New Scientist

SPECIAL ISSUE

WEEKLY 14 January 2023

THE SURPRISINGLY SIMPLE SECRET TO BEING HAPPY

AI LAWYER TO GET ITS DAY IN COURT

HOW PARTS OF YOUR BRAIN SPEED UP AS YOU AGE

WHY WORST-CASE CLIMATE SCENARIOS ARE NO LONGER LIKELY

THE LIMITS OF KNOWLEDGE

When measurement is impossible

When things are outrageously complicated

When maths is unreliable

When we can't directly experience something

When logic itself might be fatally flawed

Plus, five questions science can't answer (yet)

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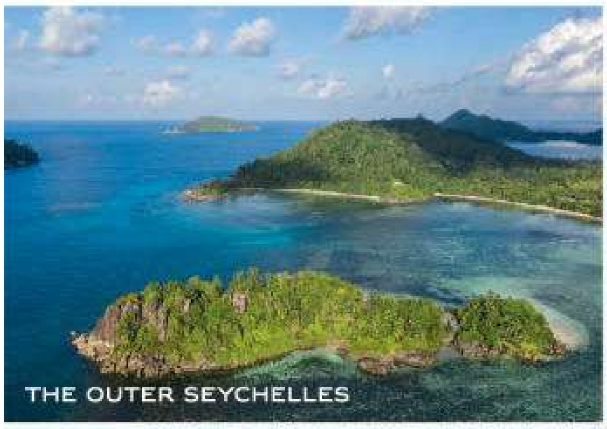
THE OUTER SEYCHELLES

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SYLVIA EARLE EXPLORES COCOS ISLAND, COSTA RICA

THERE ARE OVER 130 HOPE SPOTS GLOBALLY

SYLVIA EARLE WITH VOLUNTEERS, THE OUTER SEYCHELLES

GREAT BARRIER REEF, AUSTRALIA

MOBULA RAYS, AZORES ARCHIPELAGO, PORTUGAL

SEA LION, GALAPAGOS, ECUADOR

ON OUR WATCH

Hope can now be spotted across all our planet's seas and oceans. Sites are made into aquatic havens by local communities, to safeguard the richness and diversity of the ecosystems they depend on. Sylvia Earle's invaluable experience as an explorer and marine biologist continues to help further their goal, through her organisation, Mission Blue. Together, they have created over 130 Hope Spots and counting. Carrying a message of hope for generations to come. It is that vision, that dedication to a perpetual planet, which we are proud to stand by. **For as long as it is needed.**

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ROLEX SUPPORTS MISSION BLUE
IN ITS COMMITMENT TO PROTECTING
30% OF THE OCEANS BY 2030

ROLEX

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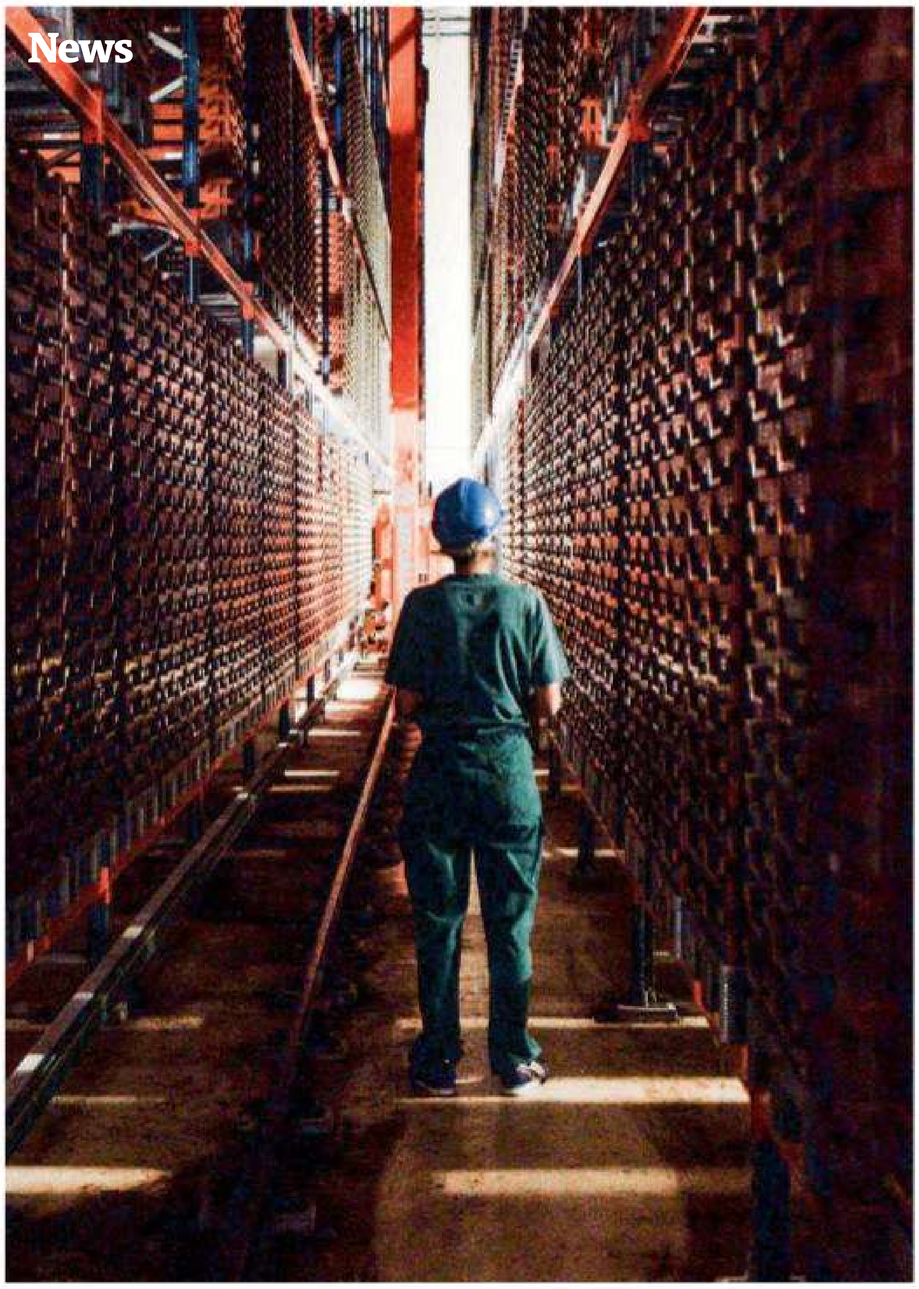

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Marine ecosystems of the Azores: Portugal

Grab an exciting chance to explore the volcanic craters and lagoons of the Azores archipelago in the North Atlantic Ocean. Alongside a team of experts, including marine biologist Russell Arnott, you will go whale spotting, visit seabird colonies and learn how the islands' volcanism supports the local viniculture. The eight-day tour begins on 13 May 2023 and costs £2999.

newscientist.com/tours

Virtual event

Secrets of the Large Hadron Collider

Join particle physicist Clara Nellist, part of the ATLAS Experiment at the LHC, for a deep dive into the past, present and future of the largest particle collider ever built. Find out how the LHC expands our knowledge of the universe, and learn what it is like to work on one of the world's greatest physics experiments. Catch it on 7 February at 6pm GMT/1pm EST. Tickets cost £14.

newscientist.com/events

Podcast

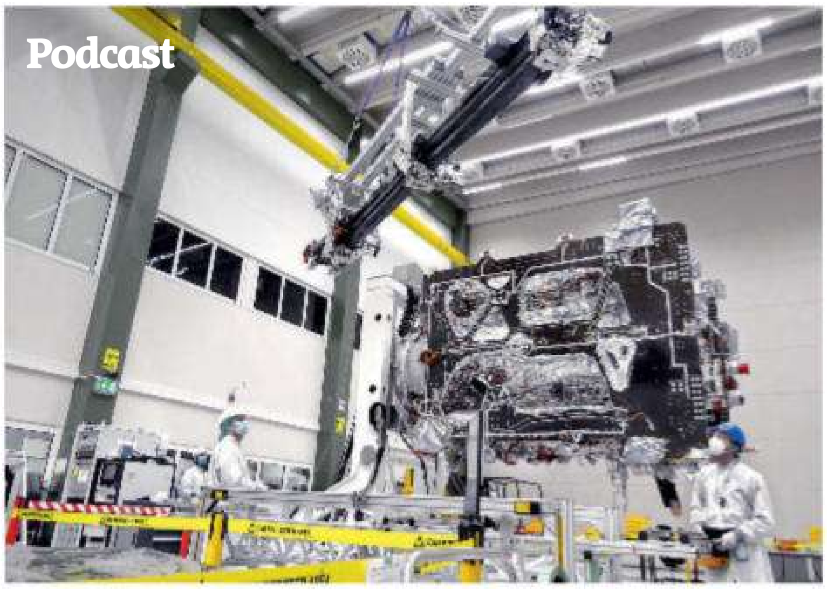
Weekly

Podcast editor Rowan Hooper hears about the JUICE and Psyche missions, which are set to blast off in 2023 – the first to Jupiter's icy moons and the second to an iron asteroid. There is also news of efforts to set regulations that will govern deep-sea mining. Plus, how synthetic embryos will improve our understanding of the earliest stages of life.

newscientist.com/nspod

GEORGE KARBUS PHOTOGRAPHY/CULTURA CREATIVE LTD/ALAMY

Making a splash Go whale watching in the Azores



AIRBUS/MATHIAS PIKELJ

One to watch The JUICE spacecraft will soon visit Jupiter

Video

Tall ship

On our YouTube channel this week, there is footage of the Voltaire "jack-up" ship, which is being used to help build the largest offshore wind farm in the world at Dogger Bank, off the north-east coast of England. The ship, which is equipped with a crane and long legs that let it "stand" on the sea floor, is 336 metres in height – just taller than the Eiffel Tower.

youtube.com/newscientist

Newsletter

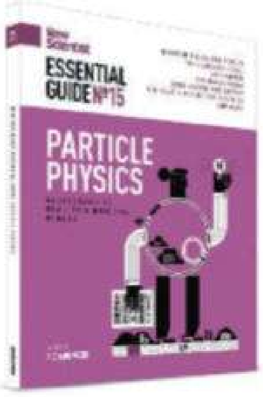
Lost in Space-Time

In 1930, Wolfgang Pauli suggested the existence of a particle with no mass and no electric charge. As physicist Suzie Sheehy explains, it took 25 years to detect his elusive particle: the neutrino. Today, we can encode messages in neutrino beams and send them through nearly a kilometre of rock.

newscientist.com/lost-in-space-time

Newsletter

> "I have done a terrible thing. I have postulated a particle that cannot be detected"



Essential guide

The past century saw a revolution in our understanding of the building blocks of reality and led to the "standard model" of particle physics. Learn about the model's history and successes, and why it is far from a final answer, in this *New Scientist Essential Guide*. Available to purchase now.

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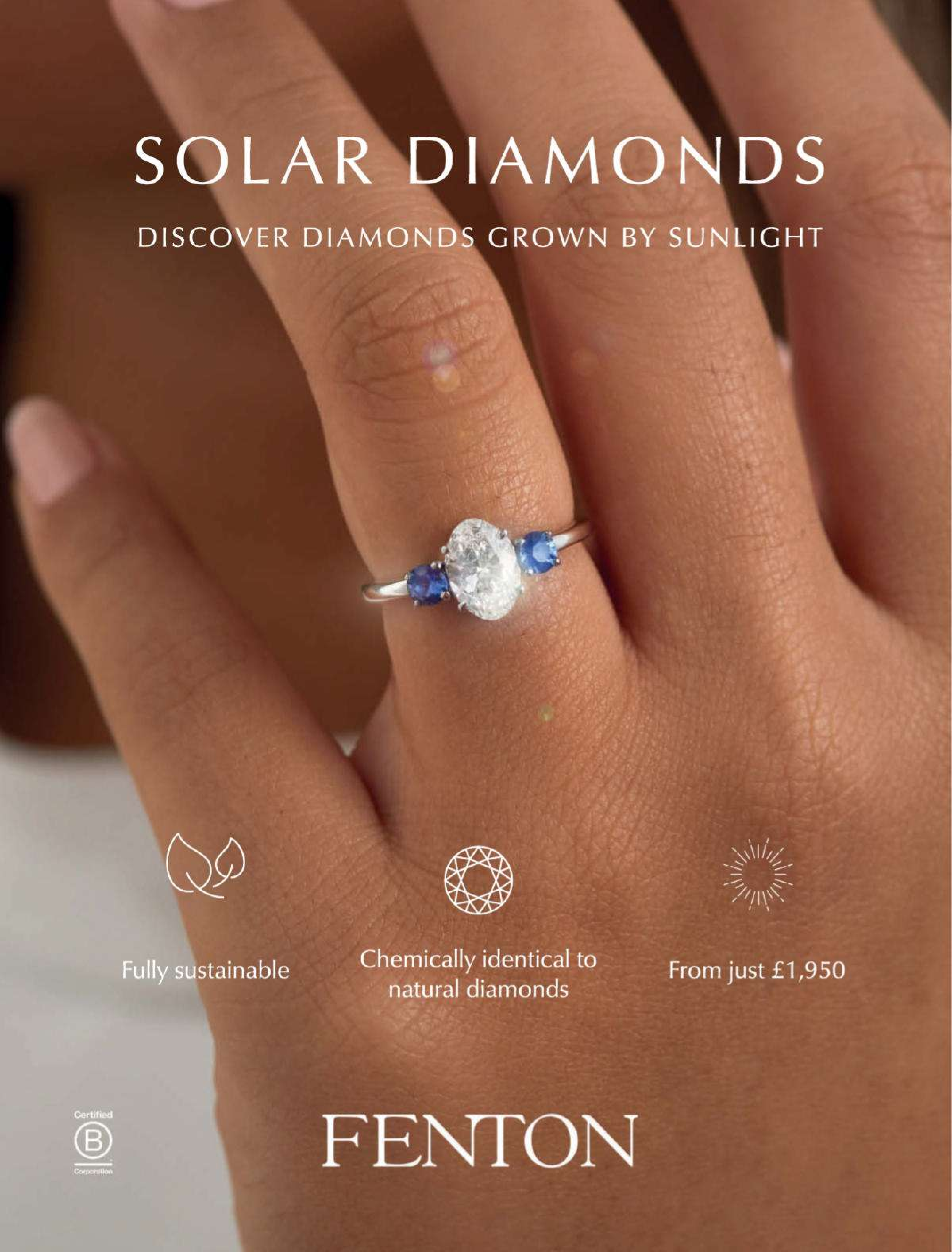
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Know your limits

Why it is important to understand what we can and can't know

SCIENCE is the culmination of humanity's attempts to reason about the world. It produces knowledge in a reliable way, and it has done so with great success. It has revealed many of nature's secrets, from the molecular machinery inside cells to the grand scheme of how the universe began and evolved to what we see today. But for all their undoubted achievements, science and reason have their constraints.

Our species is unique (as far as we know) in its ability to know what we don't know. That alone might make us duty bound to explore the limits of knowledge and understanding. More than that, however, these limits represent the hinterlands of what is knowable and what isn't. Exploring them, as we do on page 38, can not only shed light on what knowledge really is, but should also lead us to knowing more.

It is helpful, for instance, to distinguish between things we can never know, owing to the fundamental constraints of the physical world, and things we don't know but could find out in future. Hypotheses are sometimes criticised for being "untestable" – string theory is perhaps the most notorious example – but we can have smarter discussions about what counts as useful if we grasp the distinction between what is physically impossible to measure and what is practically impossible with current technology.

> "These limits represent the hinterlands of what is knowable and what isn't"

We also find that some deep limitations to knowledge spring from our magnificent brains. Mathematics and logic are the most fundamental of the tools we have invented to accrue insight and, though they might seem unimpeachable, they have their own pitfalls. No one would suggest they should be abandoned, but perhaps we ought to devote more energy to considering if they could be improved.

Ultimately, the main reason to explore the outer limits of knowledge might simply be because it is exhilarating. This magazine has the pleasure of reporting on fresh discoveries every day. But, arguably, it is what we don't know that really intrigues us – and what we cannot know might be more intriguing still. ▮

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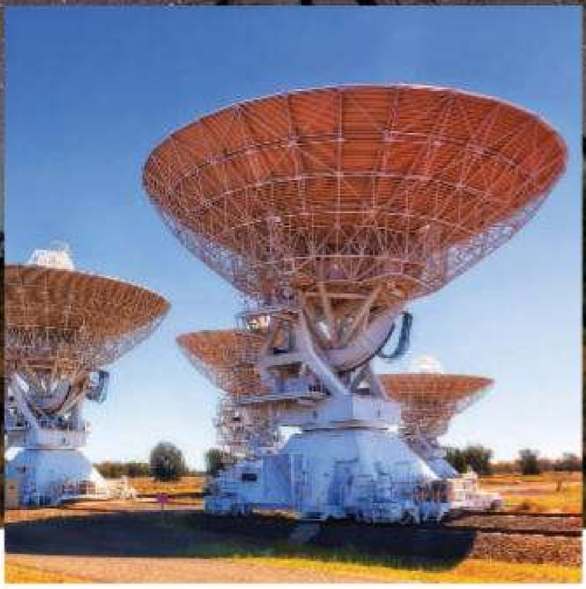
Trips of a lifetime this spring



27 March 2023 | 12 days

The world capital of astronomy: Chile

With unique geographical and climate conditions and 70 per cent of the world's telescopes, Chile truly is the world capital of astronomy.

Accompanied throughout by *New Scientist* astronomer and features editor Abigail Beall, this tour will take you to world-leading observatories, including ALMA and Paranal. You will gain hands-on experience at historic and modern observatories, meet local experts and stargaze at several sites near San Pedro, Santiago and Vicuña.

Plus, enjoy the amazing landscapes of the Atacama desert, traditional cuisine and the fascinating towns and cities of this highly stimulating country.

9 April 2023 | 8 days

Astronomy and radio telescopes in New South Wales: Australia

Discover why Australia has played such an important role in radio astronomy and NASA missions by visiting its famous telescopes and observatories, while enjoying stargazing at the southern hemisphere's celestial wonders.

Travelling from Sydney across New South Wales, you will visit the Canberra Deep Space Communication Complex, Parkes Observatory and the isolated Australia Telescope Compact Array. Enjoy historical and atmospheric outback towns that offer access to some of the darkest skies. Plus, explore the geological marvels of Warrumbungle National Park, and the vibrant cities of Sydney and Canberra.

16 April 2023 | 10 days

Total Solar Eclipse 2023: Cruise Indonesia

Join a sea adventure like never before. Sail out over the eastern seas of Indonesia to witness a total solar eclipse whilst on an uninhabited tropical atoll that sits within the eclipse line of totality.

This a brand-new cruise aboard a 22-berth luxury crewed schooner visiting several remote islands well off the tourist trail in the Banda sea. The highlight of the cruise will be the eclipse day, where you will disembark onto the beautiful Maupora atoll, an exotic uninhabited island. You will experience colourful coral reefs, marine biology, white sand beaches, abundant wildlife and the traditional Indonesian small island culture that Alfred Russell Wallace enjoyed in the 1850s.

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AI slowdown Machine learning set to stagnate due to lack of data p12

Urban reptiles Lizards have gene mutations for city living p12

Childhood adversity How early-life hardship is etched in the brain p14

Exotic meteorites Interstellar rocks may come from supernovae p19

Pregnancy health Gene variants linked to pre-eclampsia and hypertension p23

KENNETH CANTRELL/ZUMA PRESS WIRE SERVICE/SHUTTERSTOCK

Flooding in Sacramento county, California, on 1 January

Environment

Capturing the storm

Heavy rain in California continues to harm the state, but plans to store rainwater could help stave off drought, reports **James Dinneen**

SWATHES of California have seen "atmospheric rivers" dump heavy rains since the end of December, with storms forecast to bring trillions more litres in January.

The deluge has wreaked havoc and led to at least 12 deaths, but it could also offer some respite to a state in the throes of a severe water crisis.

While some of the stormwater will top up depleted reservoirs and aquifers, much of it will flow off pavements and farmland into rivers and drainage systems to be carried out to sea. Several projects are testing efforts to capture water before it is lost.

"Historically, we've viewed stormwater as a nuisance," says Andrew Fisher at the University of California, Santa Cruz. "The approach that a lot of places have taken is to get it off the landscape as quickly as possible."

The water crisis in the western US is changing that thinking. Across California, water managers and researchers are focusing on "managed aquifer recharge" to capture as much stormwater as possible underground.

The approach has been around for decades, but it wasn't a priority when water could be imported from elsewhere and deficits could be made up by pumping groundwater, says Richard Luthy at Stanford University in California. "The day of reckoning hadn't come yet."

It has now. Climate change has reduced snowpack – the state's largest store of water – and a drying Colorado river offers less water to import. A recent study found that California's heavily irrigated Central valley has lost around 2 cubic kilometres of groundwater to unsustainable pumping each year since 1961.

570bn

Capacity of proposed Californian water recharge projects, in litres

The crisis has spurred a hunt for other sources of water. "People are serious about this," says Rob Gailey, a water consultant working on a project in Central valley to pump stormwater from an underused canal into wells. He says a single well can add around 1 million litres of water per day to the aquifer below it during the right conditions. Other projects flood fields outside the growing season or flood crops that can tolerate the water.

In the San Francisco Bay Area, the Alameda County Water District maintains inflatable rubber dams that can divert stormwater flowing in creeks into gravel quarries, where it seeps down into the groundwater basin.

"We're sipping off of those big flows," says Fisher, who has a test project diverting stormwater running off hillsides into a basin in the Pajaro valley near Santa Cruz. "We're taking a fraction of that water, we're slowing it down and we're getting it to locations where it can get into the ground."

There are growing efforts to capture more stormwater in urban areas as well. Luthy points to two parks under construction in Los Angeles and San Francisco that double as aquifer recharge sites. A report from the Los Angeles Department of Water and Power found that the city could feasibly capture enough stormwater to supply roughly a quarter of its water by 2035.

There are many obstacles to expanding recharge projects, from securing water rights and land to dealing with contamination, which can be a problem with runoff from both urban and agricultural land. But "we're looking at stormwater differently in the 21st century", says Luthy.

In all, 340 local recharge projects have been proposed in the state, according to a report by Californian state water agencies. If all of these were built, they could store around 570 billion litres of water in a wet year. ▮

Artificial intelligence

AI will advise a defendant in court

An artificial intelligence is set to tell a defendant what to say during a court case over a speeding fine. It is likely to be the first case defended by an AI, reports **Matthew Sparkes**

AN ARTIFICIAL intelligence is set to advise a defendant in court for the first time ever. The AI will run on a smartphone and listen to all speech in a courtroom in February before instructing the defendant on what to say via an earpiece.

The location of the court and the name of the defendant are being kept under wraps by DoNotPay, the company behind the AI. But it is understood that the defendant is charged with speeding and will say only what DoNotPay's tool tells them to via an earbud. The case is being considered as a test by the firm, which has agreed to pay if any fines are imposed, says its founder, Joshua Browder.

SAUL LOEB/AFP VIA GETTY IMAGES

$1 million is on offer to use an AI lawyer at the US Supreme Court

DoNotPay is also offering $1 million to anyone with an upcoming case at the US Supreme Court if they will do the same thing, though the details of this are still to be confirmed.

Using a smartphone or computer connected to an in-ear device in court is illegal in most countries, but DoNotPay has found a location where this set-up can be classed as a hearing aid and therefore allowed, says Browder. "It's technically within the rules, but I don't think it's in the spirit of the rules," he says.

Browder says he has used the AI to talk directly to customer service staff at a bank with a synthesised voice, and it successfully reversed several bank fees on its own.

"It's the most mind-blowing thing that I've ever done," says Browder. "It's only $16 that we got reversed, but that's the perfect job for AI – who has time to waste on hold for $16?"

DoNotPay was launched in 2015 as a chatbot that provided legal advice on consumer issues, relying heavily on templated conversations. The firm started focusing more on AI in 2020, when OpenAI released a public programming interface for people to tap into the abilities of GPT-3, its language-processing AI.

Browder says it took a long time to train the DoNotPay AI on the vast amounts of case law needed to make it useful. DoNotPay's AI app now covers a wider range of topics, including immigration law, and the company claims it has intervened in about 3 million cases in the US and the UK.

The AI had to be trained to stick to factual statements, rather than saying whatever it could to win a case regardless of truth.

"A lot of lawyers are just charging way too much money to copy and paste documents"

"We're trying to minimise our legal liability," says Browder. "And it's not good if it actually twists facts and is too manipulative."

The audio tool has also been tweaked to not automatically react to statements every time. "Sometimes silence is the best answer," says Browder. He says his goal is that the software will eventually replace some lawyers.

"It's all about language, and that's what lawyers charge hundreds or thousands of dollars an hour to do," he says. "There'll still be a lot of good lawyers out there who may be arguing in the European Court of Human Rights (ECHR), but a lot of lawyers are just charging way too much money to copy and paste documents and I think they will definitely be replaced, and they should be replaced."

Nikos Aletras at the University of Sheffield, UK, who has created an AI that can accurately predict the outcome of cases at the ECHR, says he has seen growing use of machine learning in the legal system. But he also warns that its adoption needs to be carefully considered.

He says that providing real-time audio legal advice in a courtroom would still be a technological challenge, and ethical and legal issues remain, such as whether it would even be legal to use.

Neil Brown at UK law firm decoded.legal says that using recording equipment in a UK court would breach the Contempt of Court Act 1981, and that courts may interpret this AI system as falling foul of that rule.

"Since it appears to involve transmitting the audio to a third party's servers and processing that audio within the resulting computer system, I'd have thought that a judge might well conclude that it was being recorded, even if deleted soon afterwards," says Brown. "So probably not something to try here unless you fancy contempt proceedings, at least not without checking it with the judge first."

But when *New Scientist* asked the UK Ministry of Justice, which oversees the justice system in England and Wales, if such a trial would be legal, a spokesperson pointed to an application process recently put in place to request a "McKenzie friend", despite it not referring to AI. These people don't have to be qualified lawyers, but defendants have the right to have them sit in court and offer advice.

"We wouldn't be able to say whether it was 100 per cent legal or not until an application was made to implement the system and our lawyers made a decision," says the spokesperson.

Brown says that AI will probably play a useful role in the legal system in the future, but that it would be likely to assist lawyers rather than replace them.

"When your lawyer tells you 'OK, let's do A', we trust them that they have the expertise and the knowledge to advise us," says Aletras. "But [with AI], it's very hard to trust predictions. We're quite far off being able to do these things reliably and get rid of lawyers. We have to be very careful of making such claims."

Space

First satellite launch from the UK failed to make orbit due to an 'anomaly'

Alex Wilkins

THE first orbital satellite launch from the UK took off from Spaceport Cornwall in Newquay, but failed to deploy its satellites to orbit.

Virgin Orbit's LauncherOne rocket, which took off attached to a modified Boeing 747 plane at 10.01pm GMT, began its ascent to orbit after about an hour into the flight, but some 25 minutes later, there was an "anomaly" and the launcher had to abort its mission.

It isn't certain whether the rocket and its satellites burned up in Earth's atmosphere on reentry or came to ground over unpopulated areas.

Thousands of people gathered near the runway to watch and cheer on the plane, Cosmic Girl, as it took off amid fierce winds and speakers blaring *Start Me Up* by The Rolling Stones.

While there may not have been much to see in the skies, there was a festival atmosphere keeping spirits high on the ground, with food trucks and a silent disco lining the runway.

Stage by stage

After Cosmic Girl left the airport, a large monitor tracked the plane's progress towards the Irish Sea, where it was supposed to deploy the rocket and its payload of nine satellites.

When the LauncherOne rocket was released from Cosmic Girl, it began its journey to low Earth orbit. The first stage successfully took it to about 12,900 kilometres per hour.

The second stage accelerated the rocket to its cruise phase at 28,000km/h. According to a spokesperson for the UK Space Agency (UKSA), the rocket reached low Earth orbit, but suffered an "anomaly" that caused it to abort its mission.

A ripple of groans and mutters of "Oh no" spread through the crowd lining the runway as spectators learned that the satellite launch wasn't successful.

The lost payload included a test satellite from Welsh company Space Forge – which it hoped to use to manufacture unique semiconductors and alloys in orbit – small military communications satellites from the UK Ministry of Defence; a pair of ionospheric monitors launched in a joint US-UK military collaboration; maritime sensing satellites from company AAC Clyde Space; a European Space Agency GPS tracker; and an imaging satellite jointly launched by Oman and Poland.

For residents of Newquay and the surrounding villages, the spectacle of a satellite launch was a landmark event. "I was born and brought up down here, I used to come to the airfield and watch all the airshows, so to find out they're going to be launching satellites from our own backyard is amazing," says Jon Grigg from St Newlyn East, a village a few kilometres south of Newquay.

"Nothing like this ever happens in Cornwall," says a resident from Bodmin, a town about 25 kilometres from Newquay.

84

Number of successful launches from the US in 2022

15

Number of launches the UK aims to have per year by about 2033

TOP: MATTHEW HORWOOD/GETTY IMAGES; LOWER: REUTERS/HENRY NICHOLLS

Cosmic Girl (above), a repurposed Boeing 747, carried the LauncherOne rocket (right) tucked under its left wing

Before Cosmic Girl had taken off, Ian Annett at UKSA told *New Scientist* that it was supposed to be an "immense moment of national pride".

Many hoped that Virgin Orbit's success would have marked the start of an era in which the UK could launch its own satellites, as well as those from other countries, from home turf. The UK's satellite building industry is second only to that of the US, but it still relies on foreign launches, such as from NASA or SpaceX, to get products into orbit.

The UK did make a successful orbital launch from Australia in 1971, but abandoned development of the technology and has been left behind by others. In 2022, the US led the pack with 84 successful launches. China's rapid progress in space capabilities meant it was close behind with 62 launches and Russia was the third most successful with 22 launches.

In 10 years' time, the UK hopes to have about 15 launches a year, says Matt Archer, director of the UK space flight programme at UKSA. This will place it on a competitive footing with countries that have more established space-launching industries, he says. The UK government hopes to eventually have a network of spaceports, including a vertical launch facility in Saxa Vord in the Shetland Islands, where a rocket launch is planned for later this year.

Launching a satellite into orbit from the UK would be the country's "Apollo moment", said UK science minister George Freeman before the launch. An attempt at launching a satellite is "a very big signal internationally that we're going to be a big player in the global small satellite launch market", he said. ▮

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Botany

Twisted branches may explain the longevity of ancient trees

Alice Klein

THE twisted, deformed shapes of very old pine trees may be a sign of an exceptional ability to adapt to stress that has helped them live for more than 600 years.

Ancient trees are important because they store large amounts of carbon, hold records of the past climate and serve as pillars of forest ecosystems. "Like old people in human societies, they connect everything," says Sergi Munné-Bosch at the University of Barcelona in Spain.

Munné-Bosch and his colleagues went hunting for ancient trees in a forest of mountain pines (*Pinus uncinata*) in Alt Pirineu Natural Park in Catalonia, Spain, combing a section of 1300 trees at high altitude that was exposed to cold, harsh weather. They chose this area since stressful conditions tend to produce the oldest trees as they have to slow their growth to cope, which ultimately extends their lifespans.

Most of the trees in the forest were around 200 years old, but the researchers found 12 ancient trees aged approximately 660 to 750 years old. They identified these rare individuals by looking for trees with trunk diameters exceeding 1 metre and estimated their ages based on the known growth rates of mountain pines (*Plant Physiology*, doi.org/jr6n).

The team noted that these ancient trees shared a number of striking characteristics. Most pine trees have a main central trunk that grows more strongly than its side branches – a trait called apical dominance – but all the ancient trees had thick side branches that competed in size with the central trunk.

JEFFREY R BADGER/GETTY IMAGES

Ancient bristlecone pine trees in Inyo County, California

These side branches often took unusual, twisted forms, suggesting these trees had a high ability to adapt to changes in the environment, known as plasticity, says Munné-Bosch.

Another common feature was that large sections of the trees were dead while the rest continued to thrive and sprout new shoots. This is another sign of plasticity, since it suggests that ancient trees can survive damage by sealing off the injured parts, says Munné-Bosch.

4850

Estimated age of the oldest known living tree in the world

The oldest known living tree is a Great Basin bristlecone pine (*Pinus longaeva*) in California called Methuselah, which is about 4850 years old. It also lives in cold, harsh conditions and has twisted branches, large dead sections and loss of apical dominance.

At this stage, it is unclear whether the unusual plasticity observed in ancient pines is a result of their age, or whether they had higher plasticity to begin with that allowed them to reach very old ages.

"It's quite difficult because the only way to answer this question would be to study individual trees over their entire lifetimes, which are hundreds of years," says Munné-Bosch.

Now that we know how to spot ancient pine trees, it should be easier to find and protect these precious individuals, he says. In the past, "it has been a problem for the scientific community to identify these really ancient trees", he says.

Although some trees can live to staggeringly old ages, they won't last forever, says Munné-Bosch. Even if they can escape human logging, they are likely to succumb to a lightning strike, wildfire, storm or other large stressor that will overwhelm their survival mechanisms, he says. ▮

Health

Genetic map made of the cells linked with endometriosis

Jason Arunn Murugesu

THE cells involved in endometriosis have been genetically mapped as part of a small study that could lead to new treatments for the condition.

Endometriosis affects around one in 10 women worldwide, according to the World Health Organization. It occurs when tissue similar to the lining of the uterus grows in other parts of the body, such as the ovaries and the tissue lining the pelvis. Symptoms include pain and difficulty becoming pregnant. It has no cure, with existing treatments aiming to ease symptoms. The cause is unknown, but the condition often runs in families.

To look for genetic links, Kate Lawrenson at Cedars-Sinai Medical Center in Los Angeles, California, and her colleagues collected more than 400,000 cells from the pelvic tissue of 21 women aged between 21 and 62. Of these, 17 had been diagnosed with endometriosis, with some cells being taken from their endometriosis-related lesions. The remaining four women hadn't been diagnosed with endometriosis.

The researchers sequenced these various cells to create a map of the genetic expressions in the cells affected by endometriosis (*Nature Genetics*, doi.org/jr7p).

The map led to the team identifying a genetic mutation whose cellular effects could one day be a target for a drug treatment for endometriosis. The mutation appears to affect the lymphatic vessels that surround endometriotic lesions. Previous studies suggest endometriotic tissue may spread around the body via the lymphatic system.

"This work indicates potential routes and targets for investigation in endometriosis," says Lucy Whitaker at the University of Edinburgh, UK. However, the endometriosis map is inconclusive given the study's small sample size, she says. ▮

Technology

AI chatbots could stagnate due to shortage of training data

Chris Stokel-Walker

THE supply of high-quality language data used to train machine-learning artificial intelligence models may run out in three years, leading AI advancement to stagnate.

Machine learning powers AI programs like text-prompted image generator Midjourney and OpenAI's chat-based text generator ChatGPT. Such models train on vast reams of human-created data to learn when asked to draw a banana, for instance, that it should be yellow or green and curved.

Now, Pablo Villalobos and his colleagues at Epoch, a group of researchers studying the development of AI, have analysed how quickly models have churned through existing data. They believe that the high-quality language data used to train models like ChatGPT will run out by 2026 and the advance in collective knowledge of AI could come to a halt soon after.

"That language is only produced by humans, and higher-quality data like books or scientific papers are costly to generate," says Villalobos.

The researchers believe that lower-quality text on which machine-learning models can be trained, such as blog posts and website text, will remain plentiful for several decades. But using lower-quality training data means gains in knowledge will become more incremental (arxiv.org/abs/2211.04325).

"A guiding assumption of contemporary AI is scale," says Gabriel Pereira at the London School of Economics. "Machine learning finds sophisticated patterns in data, and, so far, by having more and more of it, the results have become better."

Chatbots like ChatGPT are trained on data sets of written language

TADA IMAGES/SHUTTERSTOCK

Until now, the language data sets used by AI models for training have grown in size by around 50 per cent each year, while the total stock of language data available to train on is only growing by 7 per cent a year, say the researchers, and so won't be able to keep up with demand.

High-quality language data is produced even more slowly and so will run out faster. "We assume that there will be no big increases in data efficiency, and also that there's no widespread use of self-training on self-generated data," says Villalobos. "If that's the case, then it seems likely that we will see a slowdown in progress over the next decades as we exhaust this training data."

OpenAI didn't respond to a request for comment about the potential shortage of new data.

Image data used to train generators such as Midjourney will last longer, says Villalobos, but the availability of both types could be extended by training models on data generated by AIs rather than humans. "It's probably one of the most promising ways to circumvent this problem," he says.

"In many machine-learning training techniques, data is routinely modified to get more mileage out of an existing data set," says independent researcher Andrew Hundt.

Such augmentation can include creating data sets by translating text into a different language and then back again or by replacing words in the original text with synonyms.

Yet modified or AI-generated data sets often include errors or bias, which can be compounded in the same way that inbreeding can affect future generations' genes.

However, Hundt doesn't think that Epoch's findings are too alarming. "Data limitations are routine in machine learning," he says, and the projection for running out of data will mainly affect just a few methods that use particularly high-quality data. ▮

Biology

Genetic adaptations to urban life found in city-slicker lizards

LIZARDS in three cities in Puerto Rico have evolved a similar set of genetic changes to help them adapt to urban life.

The Puerto Rican crested anole (*Anolis cristatellus*) is abundant in cities, but living there presents challenges. There are fewer dense bushes to hide in, glass and metal surfaces are much smoother and harder to climb than tree bark and much of their diet consists of human garbage rather than the berries and insects they are used to in the forest.

Kristin Winchell at New York University and her colleagues have already discovered that the city lizards have longer limbs to run faster across open spaces and larger, stickier toe pads than the rural lizards to help them climb smooth surfaces. But the researchers wanted to know how these changes were happening at the genetic level.

To find out, they collected tissue samples from lizards in three cities in Puerto Rico, as well as in the surrounding countryside, then compared their DNA. Even though the three urban populations were genetically distinct, each had mutations in the same groups of genes – a textbook case of parallel evolution (*PNAS*, DOI: 10.1073/pnas.2216789120).

"No matter how we looked at it, urban lizards keep experiencing the same changes," says Winchell, which shows that this species of lizard adapts to deal with pressures of urban life in predictable ways.

"These animals seem to adapt to deal with the pressures of urban life in predictable ways"

One group of genes involved in urban adaptation was associated with immune function and with metabolism, which makes sense, says Winchell, since city lizards have a different diet and are exposed to more injuries and parasites than rural ones. Another was associated with limb and skin development.

Although these changes may bring some advantages in the city, there could be evolutionary trade-offs, effects that aren't great overall, says Kevin de Queiroz at the Smithsonian National Museum of Natural History in Washington DC. ▮

Brian Owens

Animals

Sloths grip stronger than humans and other primates

Jake Buehler

WITH one foot, sloths can exert a force far beyond the grip of humans and other primates, relative to their body weight.

Melody Young at the New York Institute of Technology and her team measured the grip of each foot on five brown-throated sloths (*Bradypus variegatus*) at The Sloth Sanctuary in Costa Rica. As they dangled from a measuring device, the sloths squeezed each fore and hind foot with a force averaging as much as 100 per cent of their body weight. That is roughly twice the proportional grip strength of humans and primates. Some individual foot tests registered nearly 150 per cent (*Journal of Zoology*, doi.org/jr9s).

Edwin Dickinson at the New York Institute of Technology says sloths have reduced musculature in their core compared with other mammals, but muscles near their feet have fast-contracting fibres associated with heightened strength.

That power can be crucial given their leisurely pace. Unlike a nimble monkey, "a sloth might be in a situation where if a branch fails, they may only be able to get one hand or foot on [another hold]", says Adam Hartstone-Rose at North Carolina State University.

The study also revealed a surprise: the sloths had a consistent and unexplained left-side bias in their strength, opposite to primates. ▮

Finley, one of the sloths that did the grip test, at The Sloth Sanctuary in Costa Rica

IGNACIO MOYA

Scientific research

Slow road to gender parity

Men set to publish more papers than women for the next 100 years

Jason Arunn Murugesu

DC STUDIO/SHUTTERSTOCK

THE number of women authoring scientific papers is increasing, but men still dominate overall and some fields won't reach gender equity until the next century, according to a major analysis.

Cassidy Sugimoto at the Georgia Institute of Technology in Atlanta and Vincent Larivière at the University of Montreal in Canada analysed nearly 5.5 million scientific papers published between 2008 and 2020, using a machine-learning algorithm to estimate the likelihood that a person's name belonged to a man or woman.

Names that were 10 times as likely to be assigned to a man than a woman were considered to belong to men, and vice versa. Around a quarter of names couldn't be classified in this way, so the pair excluded them from the rest of the analysis. They also didn't include any other genders in their work.

The pair found that, in general, the percentage of women contributing to scientific papers increased each year. For example, only 43 per cent of authors in psychology were women in 2008, but this figure reached 50 per cent in 2021. Extrapolating forwards, they estimate that men and women will reach equal levels of authorship in biology in 2069 and chemistry in 2087.

However, many sciences won't achieve parity until the next century, based on current rates of progress. The pair found that engineering will only reach gender parity in 2144, while mathematics and physics will have to wait until 2146 and 2158, respectively.

2158

Year that physics is due to reach gender parity

They also found that papers written by women for high-profile journals such as *Nature* and *Cell* were less cited than those written by men for the same publications. "It points to some kind of bias in the system," says Larivière. He is unsure as to what may explain the discrepancy. "It's not specific to one field," he says. "It's really there in every discipline."

Biologists are set to reach gender equity in research by 2069

The pair's research is part of a book called *Equity for Women in Science*, which is due to be published later this year and details the many ways that scientists, policy-makers, funders of research and science communicators can help to close this gap.

"There are no quick fixes," says Sugimoto. "At a micro level, scientists need to change how they recruit students and how they promote."

"Quotas work: they are ways for people to go beyond what is their gut reflexes of what's in their close networks and actually find the people that contribute to the diversity of the scientific community," she says.

On a wider level, funding agencies and institutions need to hold themselves accountable for increasing diversity in science, says Sugimoto.

Having equity in science between men and women is important for multiple reasons, says Sugimoto. "The diversity in the scientific workforce changes the content of research and it makes research more representative of the population," she says. "This expands the breadth of possible questions."

Billie Bonevski at Flinders University in Australia says this research makes clear that systems have to change, not women themselves.

"Gender equity in science and STEM holds so much promise for new ideas, perspectives and solutions," she says. "Without the inclusion of half the world's population, we are not working at optimal levels." ▮

Neuroscience

How childhood adversity may influence the adult brain and mental health

Grace Wade

A NEWLY identified brain pathway in mice could explain why experiencing hardship early in life leads to poorer mental health as an adult. If a similar pathway is found in human brains, it could be the target of future drug therapies.

During childhood, "poverty, immigration, neglect and abuse are all associated with an increased risk for mental health issues later in life, specifically depression, drug use and even suicide", says Tallie Z. Baram at the University of California, Irvine.

The precise mechanisms underlying this association are unknown, but it may be related to the fact that stress can cause connections between brain cells to either strengthen or weaken as the brain develops. Baram and her colleagues looked at the brains of nine adult male mice, which had been engineered to make a stress-sensitive brain molecule glow when viewed under a microscope. It allowed the team to map how the molecule travelled to reach the nucleus accumben, a brain region involved in pleasure and reward.

ADAM ANGELIDES/DIGITAL VISION/GETTY IMAGES

A difficult childhood is linked with poor adult mental health

This revealed a new pathway connecting this region to a part of the brain linked to fear and anxiety called the basolateral amygdala (bioRxiv, doi.org/jr6m). "It made sense that because this [molecule] is stress sensitive, that maybe early-life adversity influences this pathway," says Baram.

To confirm their suspicions, the researchers activated the pathway in adult male mice using optogenetics, which uses light to turn cells on and off. This decreased the animals' interest in pleasurable activities, such as sex and eating sugary foods. "They almost looked depressed," says Baram. "And this is exactly what we find in adult male mice that have been exposed to early-life adversity."

Conversely, turning off the pathway in mice raised with limited bedding materials, which is meant to mimic early-life adversity, restored their interest in these activities. On average, the mice ate about 30 per cent more sugary food and displayed greater enthusiasm for sex than before. "They became normal. It was actually incredibly striking," says Baram.

Together, these findings hint at a potential mechanism for the long-term mental health consequences of childhood adversity. However, because only male mice were studied, future experiments are needed to determine how this pathway affects females, says Baram.

It would also be useful to assess how this pathway relates to dopamine, a chemical that induces feelings of pleasure and reward, says Sora Shin at Virginia Tech. "That might help validate not only the function of this pathway, but the neurochemical mechanism of it," she says.

> "Stress can cause connections between brain cells to either strengthen or weaken"

If these findings translate to humans, they could make treatments for depression and other mental health conditions related to early-life adversity more effective, says Shin. ▮

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Geophysics

Background cooling effect of volcanoes underestimated

VOLCANOES are emitting up to three times more climate-cooling gases than previously thought, according to an analysis of tiny particles in a Greenland ice core.

Sulphate aerosols have a cooling effect on the climate by altering clouds and reflecting solar radiation. Gases released by volcanoes, marine phytoplankton and the burning of fossil fuels all contribute to the production of sulphate aerosols, but measuring the contribution from each source is very hard, so there is uncertainty about their climate impact.

FRANCESCO RICCARDO IACOMINO/GETTY IMAGES

To resolve this, Ursula Jongebloed at the University of Washington and her colleagues looked at sulphate particles trapped in Greenland ice. By gauging levels of various isotopes of sulphur, they could tell how much sulphate came from volcanoes and how much from marine sources between 1200 and 1850.

They found that volcanic sulphate emissions were much higher than expected. Even in the years without major eruptions, some two-thirds of the sulphate came from volcanoes (*Geophysical Research Letters*, doi.org/jr6p). "This suggests that degassing from non-erupting volcanoes is far more important than we thought," says Jongebloed.

Volcanoes emit gases that have a cooling effect on the climate

Consequently, the team estimates that the cooling effect of human-made sulphate may only be half as potent as thought. "It may explain why climate models are not quite able to replicate the high levels of warming we see in the Arctic," says Jongebloed. In other words, if you dial down the cooling effect of our sulphate pollution, the models might better replicate Arctic warming.

"It's a really interesting study and it is certainly possible that we've underestimated the impact of volcanic degassing globally, but aerosols don't travel far from their source, so we can only draw conclusions about the Arctic region from this ice core," says Nicolas Bellouin at the University of Reading in the UK. ▮

Kate Ravilious

Quantum hack isn't ready yet

A claim that quantum computers can break modern encryption methods has been met with cautious scepticism – but it could happen one day, finds **Matthew Sparkes**

A GROUP of researchers has claimed that quantum computers can now crack the encryption we use to protect emails, bank accounts and other sensitive data. Although this has long been a theoretical possibility, existing quantum computers weren't yet thought to be powerful enough to threaten encryption.

However, security experts have expressed doubts about the new claim, saying that although the code-breaking technique appears valid, there is no reason to think that it could crack encrypted data in a practical timescale or that current quantum hardware is even reliable enough to run it.

Modern encryption algorithms are based on mathematical problems deemed too hard to be cracked in a reasonable time, even by the fastest conventional computers available today. For example, the widely used RSA algorithm relies on the fact that multiplying two prime numbers to generate a large encryption key is easy, while finding those original prime factors when you only have the encryption key is very difficult.

But quantum computers can exploit the unusual properties of quantum physics to speed up some calculations and will probably render current encryption techniques obsolete once the hardware is sufficiently powerful and accurate.

A technique to find prime factors on a quantum computer, known as Shor's algorithm, was first developed in 1994, but it is thought that cracking today's encryption using this algorithm would require a computer with millions of qubits, or quantum bits – far larger than any in existence.

Now, Bao Yan at the State Key Laboratory of Mathematical Engineering and Advanced Computing in Zhengzhou, China, and his colleagues have used a small quantum computer to calculate the prime factors of the number 261,980,999,226,229, which they say is a record for quantum computing. The team claims to have improved on the efficiency of Shor's algorithm by building on work published in 2021 by mathematician Claus-Peter Schnorr, who boldly said that it "destroys" RSA.

Schnorr's work proved controversial because other researchers found that it rapidly loses efficiency for larger numbers, meaning it is no threat to practical RSA encryption, which today uses at least 2048-bit numbers, so called because they are 2048 digits long when written in binary.

But Yan and his colleagues have used a new method to factor 261,980,999,226,229 – a 48-bit number – with just 10 qubits, and estimate that they only need 372 qubits to break a 2048-bit number (arxiv.org/abs/2212.12372). Although the researchers didn't have access to a large enough machine to test this, such devices do exist: for example, IBM has a quantum computer called Osprey that contains 433 qubits.

The researchers didn't respond to a request for interview and their paper doesn't mention how long their quantum computer took to crack the 48-bit number, or whether it was carried out faster than would be possible on a conventional computer, where the record for factoring is for an 829-bit number. They do, however, claim in their paper that their finding means RSA encryption is at risk from even today's small, error-prone and cumbersome quantum computers.

> **"Encryption algorithms are based on mathematical problems deemed too hard to be cracked quickly"**

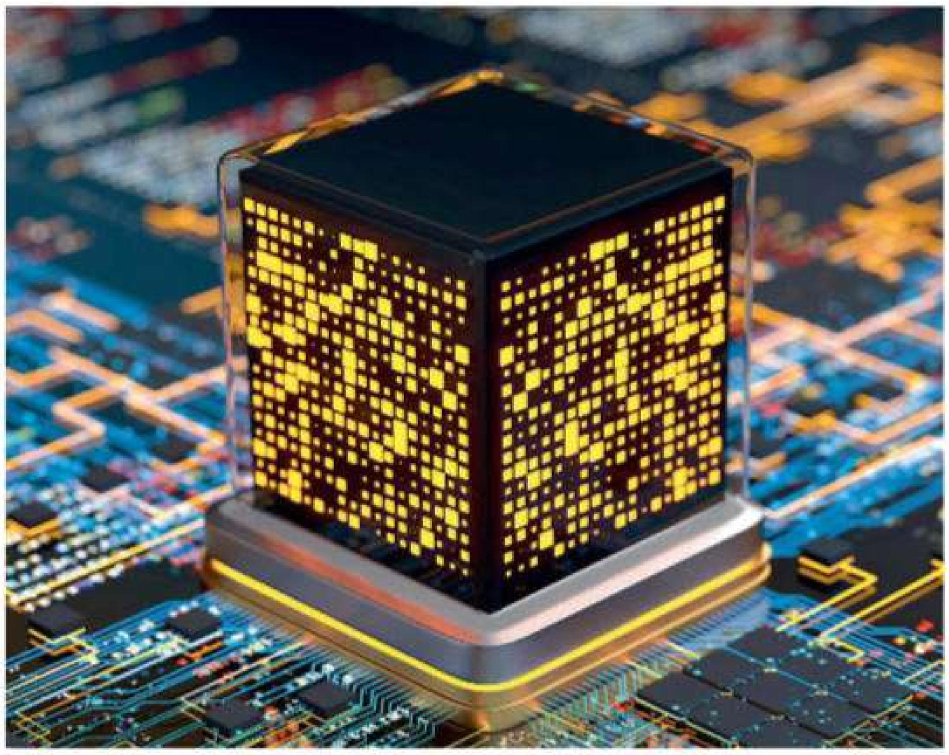
"If this is true, then indeed we're in big trouble," says Lukasz Olejnik, a cybersecurity consultant based in London and Brussels. He says the number of qubits needed to decrypt a 2048-bit number is probably much higher than 372, as "logical" qubits composed of several physical qubits are required to control errors. "So it's not a viable attack for the next few years at least. However, if the results stand, it should be testable soon," he says.

Dustin Moody at the US National Institute of Standards and Technology, which recently recommended encryption algorithms that should be safe from quantum computers, says the paper has no obvious mistakes, but should be carefully analysed.

"Cryptographers will be a bit sceptical until some review suggests this newer paper is promising, since it starts with the Schnorr paper," he says. "One or two smart people I trust have read it and said they have doubts. It's premature to say this threatens RSA-2048."

Josh Nunn at quantum computing start-up Orca Computing says that more work will need to be done before it is known whether the new approach does genuinely find prime factors faster than previous methods, and whether it will scale to the large numbers involved in secure encryption. He says that although today's quantum computers may have the number of qubits required in theory, they are too inaccurate to carry out the large calculations that would be needed and errors would accrue over time.

"You would just have gibberish by the end," says Nunn. "It is beyond the reach of current technology, but it's not obvious that it's wrong or something that needs to be just dismissed. I think it will probably galvanise the community." ▮



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Quantum computers that can hack encryption aren't quite with us yet

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Field notes Dole, France

Are robotic insect farms the future of food?

A French company is hoping its dried mealworms will replace some of the meat in our diets. **Alex Wilkins** pays its pilot factory a visit

IT IS winter in the French town of Dole, but inside the factory where I am standing, the temperature is above 25°C (80°F) and the humid air has a distinctive earthy odour. Robot arms and automated conveyor belts transport stacks of red trays in every direction. The trays are filled with the factory's raw material: billions of *Tenebrio molitor* beetle larvae, commonly known as mealworms.

This automated mealworm nursery and slaughterhouse is the blueprint for a global network of insect farms planned by French biotech company Ÿnsect. Its products so far have been chemical fertilisers for plants, pet food and farm feeds for pigs and chickens. But mealworms were approved for human consumption in the European Union in 2021 and the company expects this market to grow rapidly in the coming years. If all goes according to schedule, it will open 15 such factories by 2030, including the world's largest insect farm in Amiens, France.

The ruinous environmental impact of the global meat industry, which uses nearly 40 per cent of all habitable land on Earth and makes up 14 per cent of human-made greenhouse gas emissions, has led to a growing drive to find alternative sources of protein. For example, in December 2022, public funding bodies in the UK announced a £16 million competition to find low-emission ways to produce food.

Many are convinced that insects will be a large part of the solution. "Insect protein is just going to grow in terms of the acceptance of it and how many people eat it – the market will grow and develop," says Olivia Champion at Entec Nutrition, an insect-based animal feed company in the UK.

TOP AND BOTTOM L: DAVE STOCK; BOTTOM R: YNSECT

Top: Growing conditions for larvae are tested in Ÿnsect's lab. Below left: *Alphitobius diaperinus* beetles, whose larvae are lesser mealworms. Below right: pet food pellets made from insect protein

Ÿnsect's dried mealworms are more than 50 per cent protein and rich in fibre and fats. They can be turned into a suite of food products, from protein powders mixed into burgers, protein shakes and cereal bars to cooking oils. This can be done at a fraction of the environmental cost of traditional farming: Ÿnsect says for 1 kilogram of protein, it uses 98 per cent less land and emits 40 times less carbon than beef, and uses 40 times less water than pork.

> **"The pilot plant in Dole is impressive, with its robotic arms and 24-hour mechanised operation"**

The mealworms in the Dole factory are fed on by-products from wheat processing. There is an assumption that all insect alternatives are more environmentally friendly than crops like soya, but this isn't a given. Some insect-food companies use carbon-intensive materials as feed, which can increase their carbon footprint, says Champion, making the environmental benefits dependent on a particular factory's set-up.

Unlike the livestock industry, where rearing is typically separate to slaughter, at Dole the entire operation is under one roof. "We are in full control of the chain of production," says Benjamin Armenjon, Ÿnsect's general manager. "That gives us strength in terms of quality, security and safety."

Meanwhile, at Ÿnsect's headquarters and research labs in Paris, the firm is experimenting with optimal rearing conditions for the mealworms, such as food, temperature and humidity. Researchers are also analysing the nutritional content of its products and the food potential of other insects, including the lesser mealworm *Alphitobius diaperinus*.

The pilot plant in Dole, with its 24-hour mechanised operation, is impressive, but it is small compared with the Amiens factory Ÿnsect is preparing to open later this year, which will produce 200,000 tonnes of insect-based products a year. With this automated, scaled-up facility, Ÿnsect hopes to bring the cost of its products down enough to compete with soya.

Whether companies like Ÿnsect and Entec Nutrition are successful at replacing meat in human diets will depend in large part on the form in which people consume the insect-based food, says Champion. A burger with insect protein in it is likely to be more palatable to consumers than fried whole mealworms, for instance. While the idea of eating insects is often met with revulsion by consumers in the West, Ÿnsect hopes that with enough education, cultural attitudes will shift over time.

Armenjon doesn't see a future in which the only option is insects, but rather one in which its products are part of an alternative meat ecosystem, with some people eating lab-grown meat and some sticking to plant-based alternatives, but he hopes some will choose insect-based foods.

"There are vegan people, flexitarians, vegetarians, meat lovers – this is fine, we don't want to change people," he says. ▮

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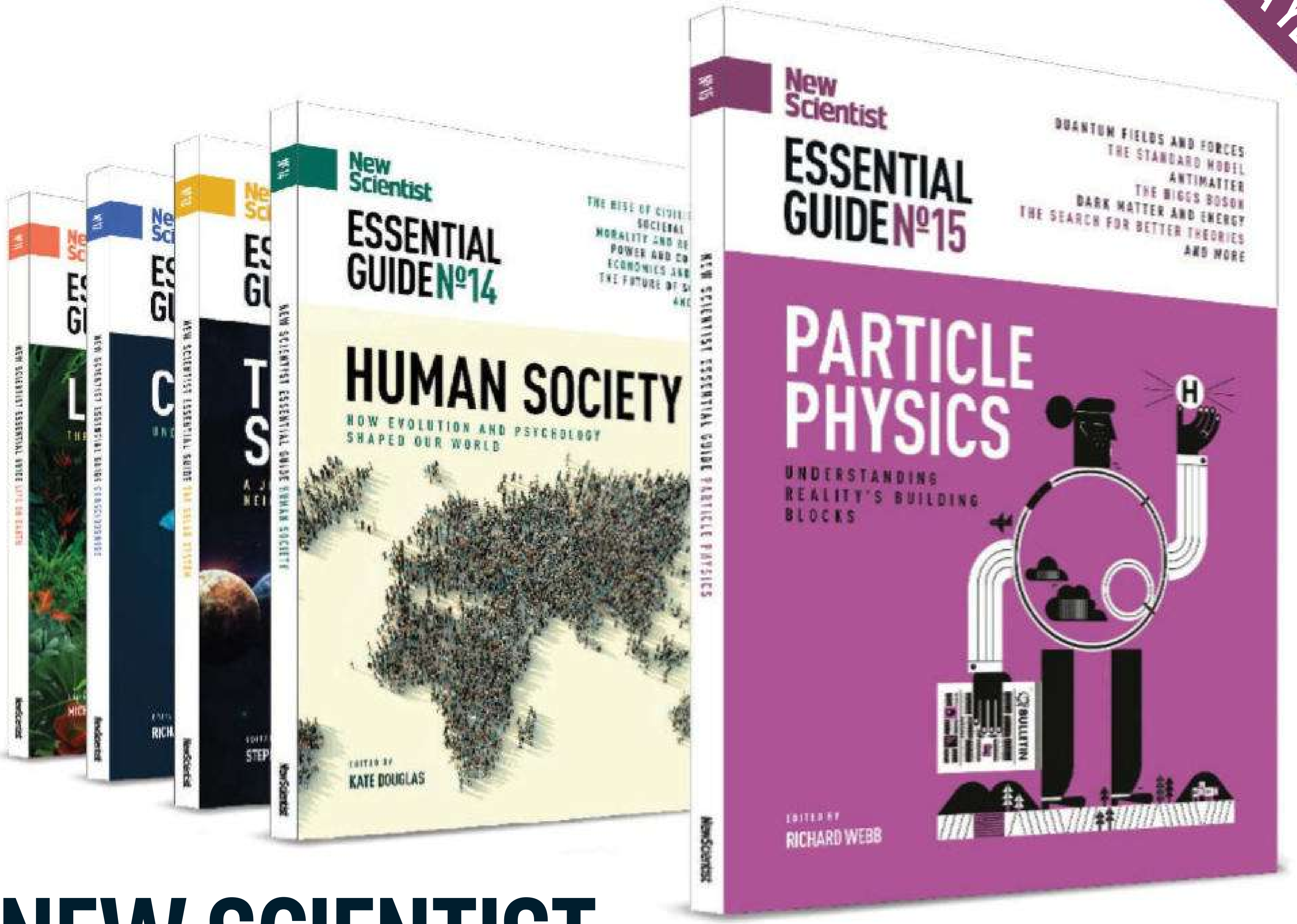

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CLARA NELLIST

Neurology

Communication within certain brain regions becomes faster as we age

Jason Arunn Murugesu

THE speed at which our neurons communicate with each other changes as we age and may increase in some regions of the brain. A better understanding of how neuron transmission speeds vary throughout a person's life may improve our knowledge of certain neurodevelopmental conditions, such as schizophrenia.

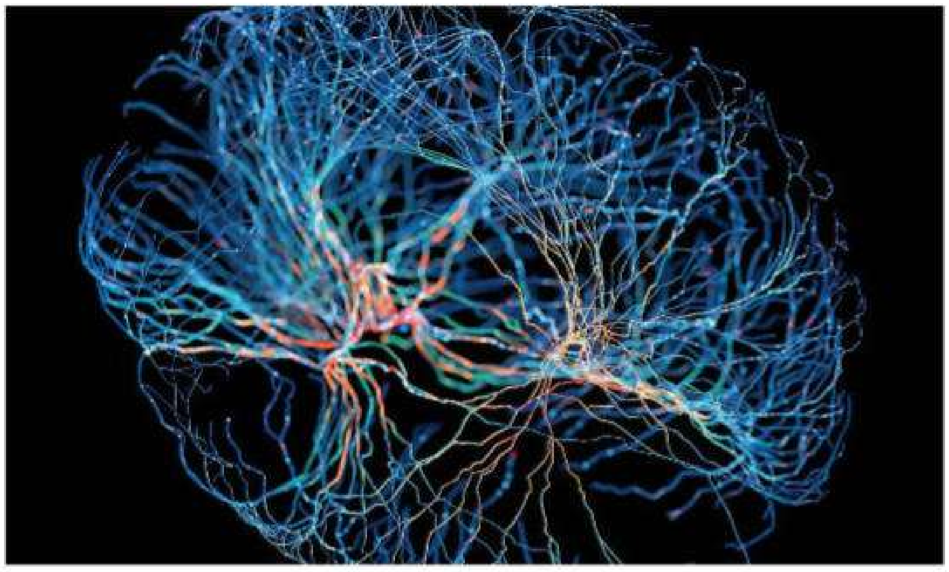
Dora Hermes at the Mayo Clinic in Minnesota and her colleagues measured neuron transmission speeds in 75 people, aged 4 to 51, while they had surgery to monitor their epilepsy. For these operations, which were carried out between 2008 and 2020, the participants had electrodes implanted onto various parts of their brain to assess the strength of their neuron responses. The researchers used this as an opportunity to measure neuron speeds in different parts of the participants' brains.

Results suggest that neuron speeds during transmission from the brain's frontal to parietal regions rise from the age of 4 to 34, before steadily declining. The same is true for transmission from the frontal to temporal regions.

In one 4-year-old participant, signals took about 45 milliseconds (ms) to travel from the frontal to parietal regions, but just 30ms to do so in a 38-year-old (bioRxiv, doi.org/jrww). Modelling suggests this would be between 21 and 27ms at 34 years old.

Yet the modelling also indicates that transmission from the temporal to parietal brain regions gets steadily faster with age.

Neuron connection speeds can increase or decrease with age


ANDRIY ONUFRIYENKO/MOMENT RF/GETTY IMAGES

This could partly be due to the brain eliminating excess synapses – the spaces between nerve cells where nerve impulses are exchanged – from childhood to adulthood, says Jonathan O'Muircheartaigh at King's College London.

In early childhood, synapse numbers rapidly rise until around 7 to 8 years old, when they start to fall, says O'Muircheartaigh. You are left with the most important synapses, he says, but whether these are also the fastest is unclear.

Myelin sheath, which surrounds nerves so impulses can be transmitted quickly, may also become thicker and more efficient in the temporal and parietal regions with age, he says.

Why the same may not occur between the frontal and parietal regions and the frontal and temporal regions is unclear, says O'Muircheartaigh.

According to the researchers, these results may improve our understanding of conditions such as schizophrenia. The exact cause of this condition is unclear, but it has been linked to problems with neuron transmission at synapses.

But Emily Jones at Birkbeck, University of London, says the study's results may not apply to people without epilepsy. Those with prolonged epilepsy may have brain changes that aren't seen in people who recently developed the condition, she says. It is unclear when the participants first developed epilepsy.

O'Muircheartaigh agrees, but says we probably couldn't implant electrodes onto the brains of people without epilepsy due to potential side effects. ▮

Astronomy

Supernovae may create interstellar meteorites

INTERSTELLAR meteorites may be even weirder than we thought. They seem to be stronger than meteorites produced in our own solar system, which hints that they could have formed in a supernova or some other extreme cosmic event.

Any meteorite travelling at a high speed compared with the sun may come from beyond our solar system, and its origin can be confirmed by calculating the direction it came from. The first interstellar meteorite discovered struck Earth off the coast of Papua New Guinea in 2014. Amir Siraj and Avi Loeb at Harvard University identified it in 2019 while digging through meteorite data collected by the US government's Center for Near-Earth Object Studies (CNEOS).

This information is primarily used to track missiles, so the details are kept private by the government. The trajectory of the object, which Siraj and Loeb called IM1, was confirmed by government scientists as interstellar. Now, the researchers have found what appears to be a second interstellar meteorite, called IM2, which struck Earth off the coast of Portugal in 2017.

They calculated the strength of all 273 meteorites in the CNEOS data based on the altitude at which they broke up in the atmosphere. "The closer it gets to the ground, the denser the air gets and the more likely the meteor is to break up," says Siraj. IM1 was by far the strongest – so strong that we aren't entirely sure what it is made of, he says – and IM2 was the third strongest (*The Astrophysical Journal Letters*, doi.org/jrwq).

"Supernovae produce these so-called 'supernova bullets' and it's possible they break up into bits"

While we can't be sure about where these two interstellar meteorites came from, one suggestion is that they could have formed in supernovae. "We know that supernovae produce these so-called 'supernova bullets', which are basically clumps of iron-rich material, and it's possible that those clumps break up into smaller bits, which could be objects like IM1 and IM2," says Siraj. ▮

Leah Crane

Technology

Supersized wind turbines could bend in the breeze

Madeleine Cuff

WIND turbines taller than most skyscrapers, with blades that bend like palm trees, could each generate 50 megawatts (MW) of power, according to an analysis of a scaled-down prototype. This would be enough to power about 15,000 US homes.

The largest existing wind turbines top out at around 300 metres tall and can generate 15MW of power. Larger turbines can produce more power, reducing the cost, but scaling up isn't straightforward because longer blades can bend in high winds and risk striking the tower. "You do not want that," says Eric Loth at the University of Virginia. "It's like an airplane crash."

Such strikes are infrequent, but the risk increases with the size of the turbine. "The reason it's very rare is because people design the turbine blades to be strong enough [to avoid bending]," says Loth. "But when you start to build 50MW, it's very difficult to do that. I don't think it's possible, to be honest."

To get around this, Loth and his colleagues are taking a different approach. Rather than having three rigid blades facing into the prevailing wind, their Segmented Ultralight Morphing Rotor (SUMR) design has two 250-metre blades mounted downwind, on the other side of a 300-metre tower. The combined height of 550 metres means the top of the blades would reach higher than the One World Trade Center skyscraper in New York.

550m

Total height of the proposed wind turbine

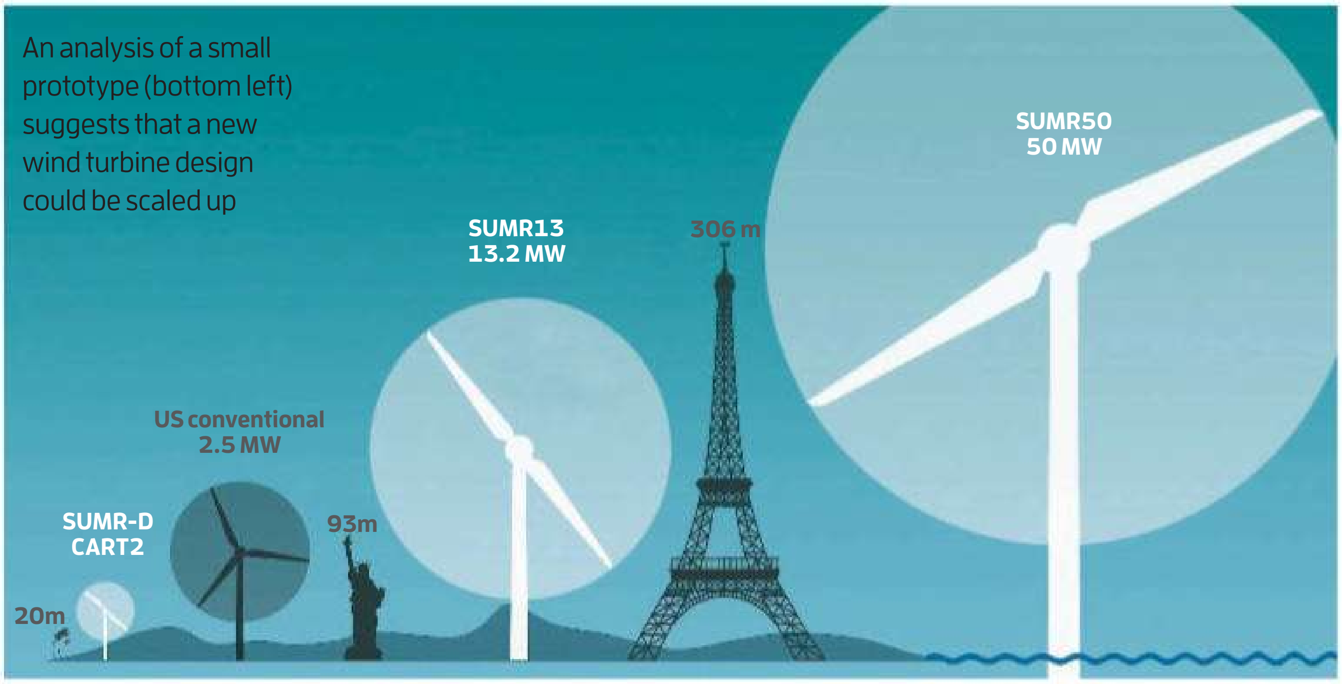
Both blades are angled away from the tower and can fold in strong winds like the fronds of a palm tree in a hurricane. "The idea is that instead of trying to fight the wind, we go with the flow," he says. "In a hurricane, the fronds [of a palm tree] can all go with the flow, even the trunk can bend down and almost touch the ground."

A small prototype of the design, with two 20-metre blades, was running at the US National Renewable Energy Laboratory in Colorado for two years until July 2022. Loth's team is now busy analysing the data from this pilot. "The technical viability looks good," says Loth, adding that it appears the design could be scaled up successfully.

But to do this, he needs to find a company with very deep pockets. "In order for us to build one, I need like $1 billion [for a prototype]," says Loth.

Gerard van Bussel at Delft University of Technology in the Netherlands says wind firms are conservative. "The industry has been very skilled and experienced in building three-bladed upwind machines," he says. "And it's a huge risk… to suddenly just change the concept." But a step change will be needed if 50MW turbines are to become reality, says Richard Cochrane at the University of Exeter, UK. "We can possibly get to 20MW the way we are doing it now, but I think beyond that it's going to need some rethinking."

The real challenge with Loth's design, says Cochrane, is to build boats, cranes and ports large enough to construct such mammoth turbines offshore. Currently, the largest turbine installation ships only reach up to 336 metres (see page 24). ▮



An analysis of a small prototype (bottom left) suggests that a new wind turbine design could be scaled up

PROF. CHRIS QIN (WASHINGTON STATE UNIVERSITY)

Cybersecurity

Wi-Fi pings might let hackers run down your battery

Matthew Sparkes

DEVICES that use Wi-Fi can be tricked into draining their own batteries, thanks to a quirk in the way that wireless networks operate.

Ali Abedi at Stanford University in California and his colleagues have discovered a phenomenon that they call "polite Wi-Fi", in which devices acknowledge and reply to messages from any other wireless device, no matter whether they have the password or permission to be on the same network.

The responses contain no sensitive information themselves, but Abedi's team has found ways that their transmission can be abused, for example by continuously pinging battery-operated Wi-Fi devices and preventing them from entering sleep mode, rapidly running down their power. This can be done with a device costing just $10 that sends out fake packets of data.

The team tested 5000 different devices from 186 manufacturers and found they were all vulnerable to this attack: if a fake data packet was sent to them, they responded with an "acknowledgement" or "ACK" signal (arxiv.org/abs/2301.00269).

Abedi says Wi-Fi devices are designed to operate this way, so they can indicate to other machines that the transmission is working. If devices waited to authenticate each other before replying, then wireless networks would virtually grind to a halt, meaning that the flaw may be difficult to fix, he says.

Kevin Curran at Ulster University, UK, says that draining batteries seems innocuous at first glance, but that it could enable dangerous attacks when packaged together with other vulnerabilities.

For example, burglars could drain the battery of a Wi-Fi-enabled security camera, he says. "If they're being pinged regularly, you can completely drain them." ▮

CONFLICT APPEAL

MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

HELP US DELIVER MEDICAL CARE BEYOND THE FRONTLINES

An MSF medic treats a patient onboard the medical train. Photograph © Andrii Ovod/MSF

CHRISTOPHER STOKES IS COORDINATING MSF'S MEDICAL WORK IN UKRAINE

23 October 2022

"On 10 October I had just left the train station in Dnipro, eastern Ukraine, when the car started shaking. A second later, we heard the blast from the first missile. By the time we reached the office, we'd felt four more shockwaves from strikes. Since then, there have been regular waves of bomb attacks targeting infrastructure and civilian areas.

We're now gearing up for the possibility that the electricity will go off across Ukraine as a result of these ongoing attacks. That will have drastic knock-on effects on hospitals, healthcare and people's lives. People are heading into winter with the risk there will be no electricity, heating or hot water.

We're doing our best to prepare. We're helping a number of hospitals near the frontline get ready. We're running mobile clinics in areas previously under Russian occupation where people have had no access to the medicines they need for months. MSF operates a specially designed medical train that evacuates patients from near the frontlines of the fighting to safer areas and we're looking at ways to keep that running, even if the electricity fails. It's been kitted out with an intensive care unit and inpatient carriages. To date, we've evacuated 1,851 patients in 60 trips, most of them suffering from blast injuries and shrapnel wounds.

Last weekend we carried one family on the train who needed to be evacuated from the war zone. They had returned to their home in Nikopol on 5 October after having fled the war months earlier. On 6 October, their house was hit by a shell. One of the daughters was badly injured and ultimately had to have both legs amputated. She was only six years old.

The Ukrainians are doing the bulk of the medical work in this war. Our role is about filling the gaps. With these latest attacks, people's medical needs are growing, and it's vital we are here."

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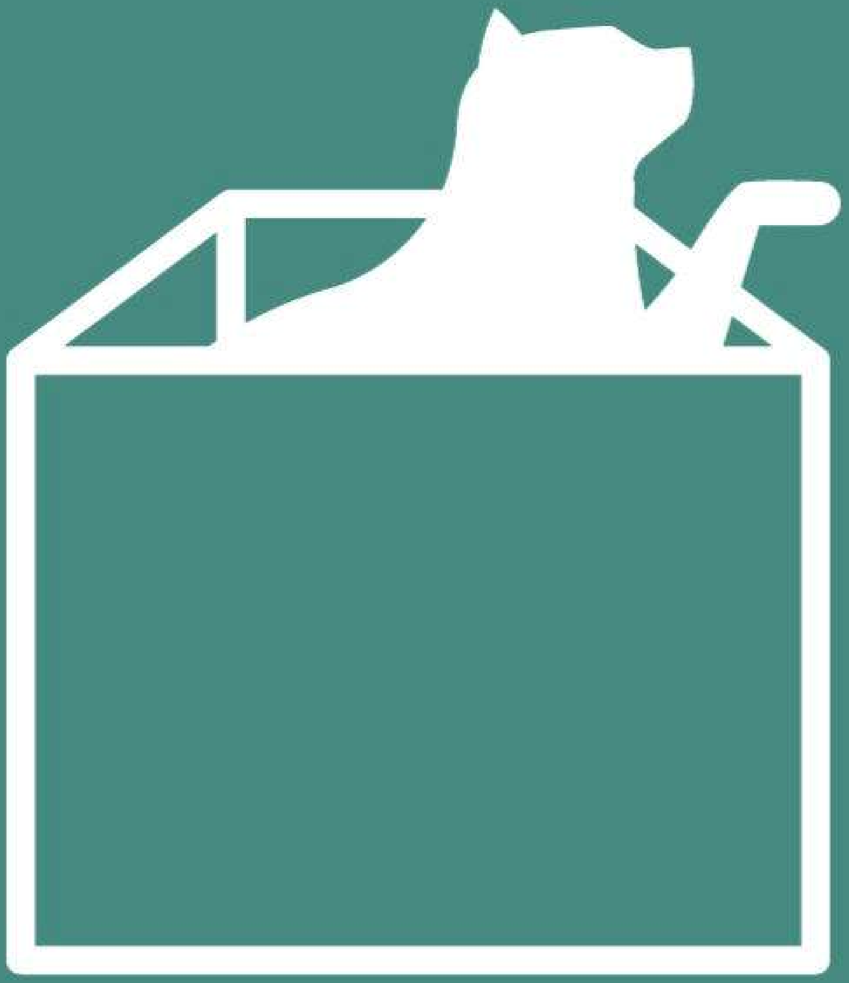

Lost in Space-Time

Lost in Space-Time is *New Scientist*'s monthly newsletter covering all that's hot in the world of quantum theory, particle physics and cosmology – plus, who knows, maybe some consciousness and reality-meets-the-human-mind stuff.

Every month, we hand the keyboard over to a big thinker in physics to tell you about an interesting – and often mind-blowing idea from their corner of the universe. We'll also point you to the most fascinating stories in physics from the previous month.

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NS

Health

Pre-eclampsia and high blood pressure in pregnancy linked to 19 gene variants

David Cox

WHY some people develop high blood pressure or pre-eclampsia during pregnancy isn't entirely understood. Now, research suggests certain gene variants may play a role.

Michael Honigberg at Massachusetts General Hospital and his colleagues have identified 19 genetic variants that are linked to the onset of either pre-eclampsia or so-called gestational hypertension. While further research is required, this could lead to genetic risk scores that gauge an individual's risk of developing either condition.

Gestational hypertension and pre-eclampsia are both defined as high blood pressure during pregnancy. The latter is also diagnosed by looking for protein in the urine, which can be a sign of kidney damage.

Both conditions require close monitoring as they can result in a premature birth or a fetus not growing as expected, and may be treated via medication or an induced labour. Other symptoms are usually mild, but, in severe cases, people can experience seizures and organ damage.

> **"Genetic risk scores could improve our ability to identify those most at risk of these complications"**

To better understand the role of genetics in the onset of these conditions, the researchers used genome sequences from global biobanks to study the genetics of 17,150 pregnant women who had been diagnosed with pre-eclampsia, 8961 who had been diagnosed with gestational hypertension and 451,241 pregnant women who had been medically certified by their doctor as having neither condition or who self-reported having normal blood pressure.

The results suggest 12 genetic variants are linked with pre-eclampsia. A further seven variants are associated with gestational hypertension (medRxiv, doi.org/jrv8).

The researchers used this information to develop condition risk scores, which they tested against genetic samples from 33,433 pregnant women, some of whom had been diagnosed with pre-eclampsia or hypertension.

When they assessed this group using clinical risk factors for these conditions, such as age, they identified 17 per cent of the pregnant women who had been diagnosed with either gestational hypertension or pre-eclampsia. When these factors were combined with the genetic risk scores, that rose to 30 per cent.

Further research is required to increase the accuracy of the genetic risk scores, says Rachel Freathy at the University of Exeter Medical School, UK. However, these could one day improve our ability to identify those who are most at risk of certain pregnancy complications, she says.

The researchers also hope the genetic risk scores could be used to gauge who may benefit from a low dose of aspirin during pregnancy, which is sometimes offered to reduce the risk of pre-eclampsia.

But Zofia Miedzybrodzka at the University of Aberdeen, UK, says using genetic risk scores to guide aspirin use may be difficult in practice due to uncertainties around its benefits and risks.

According to Honigberg, a low dose of aspirin during pregnancy is relatively low risk, so treating people unnecessarily isn't a huge concern. ■

Ecology

Reef fish feel knock-on effects of invasive rats

DR RACHEL GUNN/LANCASTER UNIVERSITY

Jewel damselfish defend patches of turf algae that grow on coral reefs

INVASIVE rat populations on tropical islands have long been known to pose a serious threat to seabirds, due to their voracious appetite for eggs and chicks, and it seems that they change the behaviour of fish around the islands too.

In the Chagos Islands in the Indian Ocean, invasive black rats can now be found on approximately 34 of the 55 islands of the archipelago. On infested islands, populations of seabirds such as boobies, frigatebirds, noddies and shearwaters have been decimated.

Fewer birds mean less bird droppings. This, in turn, means a fall in nitrogen and phosphorus in the waters surrounding the islands, which support the growth of algae on coral reefs.

Rachel Gunn, then at Lancaster University, UK, and her colleagues placed underwater cameras in 60 locations around the archipelago to see how this change in nutrient flows affects the behaviour of jewel damselfish (*Plectroglyphidodon lacrymatus*). These fish aggressively guard patches of turf algae that grow on coral reefs and "farm" them by weeding out the algae they don't eat.

Compared with other islands, the fish around rat-infested islands farmed larger patches because the algae were less nutritious, and they were also less aggressive (*Nature Ecology & Evolution*, doi.org/jrw4).

"Aggression and territory defence is a really high-energy behaviour, so it requires a high level of nutrients in order for that behaviour to be carried out," says Gunn. It isn't worth investing extra energy to defend a larger territory with lower value, she says.

The behavioural effects on fish are yet another reason to press ahead with the eradication of invasive rats on tropical islands, says Gunn. ■

Madeleine Cuff

Biology

New part of our brains discovered

A NOVEL anatomical structure has been found in the brain's waste disposal system.

The tissue is a thin membrane encasing the brain that keeps freshly made cerebrospinal fluid – which circulates inside the brain – separate from "dirty" fluid that contains cellular waste products.

It was already known that there are three membranes between the skull and brain. The latest addition is the subarachnoid lymphatic-like membrane (SLYM). It is extremely thin, usually just a few cells wide (*Science*, doi.org/grk4fv).

The SLYM hadn't been noticed before, partly because it disintegrates when the brain is removed in post-mortems, says Maiken Nedergaard at the University of Rochester Medical Center in New York, who helped discover it. **Clare Wilson**

Bioengineering

Penises enhanced with artificial flesh

SYNTHETIC tissue restored the erectile function of pigs with injured penises, an advance that may one day help treat impotence.

The artificial tissue mimics a layer called the tunica albuginea that surrounds a spongy region, which fills with blood during an erection. Although promising, the researchers acknowledge that erectile dysfunction can have multiple causes, including injuries outside of this tissue.

Xuetao Shi at the South China University of Technology and his colleagues used isotropic polyvinyl alcohol gel to create an artificial tunica albuginea with a curled fibre structure, similar to that of the natural tissue.

They tested it in pigs with an injured tunica albuginea. The penises became erect when the organ was injected with saline (*Matter*, doi.org/jrw6). **Sara Novak**

PARALAXIS/ALAMY

Environment

Changes in Amazon linked to climate in far-flung areas

RAPID deforestation in the Amazon could influence temperature and precipitation over the Tibetan plateau 15,000 kilometres away.

Saini Yang at Beijing Normal University in China and her team analysed global climatological data from 1979 to 2019 to identify correlations between conditions in the Amazon rainforest and climate in other areas. Such links are called "teleconnections".

They focused on the Amazon in particular because of its significance as a major carbon sink and as a climatic "tipping point" that could see forest turn to savannah beyond a certain threshold of warming and human-driven deforestation.

The team found that since 1979, warm temperatures in the Amazon correlated with warm temperatures over the Tibetan plateau and the West Antarctic ice sheet; more precipitation in the rainforest was associated with less precipitation in those regions (*Nature Climate Change*, doi.org/jrwz).

The collapse of the West Antarctic ice sheet is a known tipping point. Melting snow on the Tibetan plateau is not, but the region is warming more rapidly than many places, and changes to snow and ice there could impact ecosystems and the billions of people that rely on its snowmelt for water, says Yang.

Victor Brovkin at the Max Planck Institute for Meteorology in Germany says the teleconnections are an interesting find, but is sceptical that variability in the Amazon causes the changes elsewhere. He says the Amazon is too small an area to overcome the influence of the tropical oceans and the researchers don't present a physical mechanism to explain any influence. **James Dinneen**

Really brief

JAN DE NUL GROUP

Ship grows taller than Eiffel Tower

A giant ship is heading to the North Sea to build the world's largest offshore wind farm at Dogger Bank, off the north-east coast of England. The Voltaire deploys four 130-metre-long legs to stand on the seafloor and can, with its crane deployed, reach 336 metres, just taller than the Eiffel Tower.

Low-carb diet cuts epilepsy seizures

Pairing a low-carbohydrate diet with typical epilepsy medications can reduce seizures in people with drug-resistant epilepsy by 50 per cent. Potential mechanisms for why it works include changes in the gut microbiome, inflammation and electrical signalling between neurons (*Neurology*, doi.org/jrwx).

Ozone layer broke in mass extinction

Earth's ozone layer, which protects life from UV light, was damaged in a mass extinction 250 million years ago, possibly by volcanic gases. Pollen and spores from this time have higher levels of "sunscreen" chemicals than those from earlier or later eras (*Science Advances*, DOI: 10.1126/sciadv.abo6102).

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PAINSHILL

Walk around a work of art at Painshill

Painshill, in Cobham Surrey, is a masterpiece of garden design. Created in the 18th century, by Charles Hamilton, it is one of the finest examples of the English Landscape Movement. A style that transformed gardens from formal geometric patterns into wild romantic landscapes and in which Britain led the world.

The landscape is open all year around and visitors are taken on a journey around a work of art through winding pathways to discover beautiful garden buildings, a serpentine lake, a vineyard, wildflower meadows and woodlands. Inspired by landscape art and designed to be viewed as a living painting, Painshill offers up a stunning view at every turn. It is a garden full of exquisite beauty and charm.

This historically important garden was lost after World War Two. Since the 1980s Painshill Park Trust have been dedicated to restoring it to its 18th century glory and hope to preserve it for future generations.

Over 40 years the Trust have painstakingly researched the garden's design, reinstated the man- made lake, replanted vast areas and rebuilt buildings, including a grand Gothic Tower, a Turkish Tent and the classical Temple of Bacchus. The jewel in Painshill's crown is the Grotto, a sparkling cave on an island in the lake filled with crystals. In the 1950s it was a ruin but it has now been rebuilt, each crystal individually placed onto the ceiling by teams of volunteers.

As a small independent charity, the Trust is only able to continue this work with the support of the general public, charitable trusts and the National Lottery Heritage Fund.

Why not treat yourself to a wonderful day out and support this incredible piece of heritage at the same time. All income generated from ticket sales, membership, the gift shop and the tea room goes back into the restoration work. Take a wander through spring flowers, sit by the lake with a summer picnic or enjoy spectacular autumn colour; it is beautiful at any time of year. Plan your visit now at painshill.co.uk

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Comment

Just like us?

Attributing human motivations and feelings to animals such as bees stifles scientific enquiry instead of encouraging it, says **Marlene Zuk**

IS PLAY the new tool use? A recent paper recounts bumblebees rolling tiny wooden balls, not for a reward, but apparently just for fun. The authors conclude that the behaviour fulfils the criteria for play, with one noting: "It goes to show… that despite their little size and tiny brains, they are more than small robotic beings." Put another way, bees just wanna have fun, and that presumably makes them more like people.

This discovery underscores a long-standing conflict in our view of animals. On the one hand, we want to find the features that distinguish humans from other animals: tools, language, a theory of mind (in which animals can infer the mental states of others). On the other, we delight in finding animals that breach those boundaries: chimps, crows and now bees that use tools, dolphins with signature whistles. But what do those boundaries mean?

SIMONE ROTELLA

Not much, or at least not what people sometimes think. As an evolutionary biologist who studies animal behaviour, I am bemused by this effort to rank animals by their capabilities. The ranking is wrong not because animals lack amazing abilities, but because evolution doesn't produce an organisation like the military, with the equivalent of amoeba privates and primate generals. Instead, everything that is alive today is just as evolved as everything else. Some species (crocodiles and cockroaches, for instance) look more like their ancient ancestors than others and may well behave more like them, but that doesn't mean some creatures are more or less highly evolved than the rest.

You might think that calling attention to bees and other animals that do things we didn't think they could do would be a way to circumvent this ranking and make our view of nature more realistic. But it isn't. It is pointless to elevate creatures, whether bumblebees or chimps, so that we can put them in an exclusive club that used to only contain humans.

Underpinning these efforts is a desire to show that animals, even tiny ones with lots of legs, are like us and shouldn't be dismissed as automatons. I applaud that desire. But we can recognise animals for what they are, and be awestruck at their abilities, without having to make their behaviour mirror that of humans. Bees may play, but that doesn't mean they are like children with exoskeletons.

Once we get out from under the tyranny of those rankings, of thinking that animals have to be like people with human motivations and feelings, we are freed up to consider the mechanisms behind the behaviours. Often, that involves convergent evolution. For example, the same neurotransmitter – serotonin – influences anxiety in humans and maze exploration in crayfish. In a tank divided into well-lit and shadowy areas, crayfish explore both, but prefer the dimmer areas, consistent with their nocturnal lifestyle. Crayfish stressed by mild electrical shocks avoided the light sections of the maze, a response that was linked to their serotonin levels and that could be altered by a serotonin inhibitor.

Does this mean crayfish experience anxiety? No, it just means that evolution co-opts similar pathways to produce different results. In the bees' case, they might be exhibiting some very interesting behaviour that has nothing to do with wanting to "have fun" – but we will never examine it if we simply assume they are playing just like people. I am not disparaging the bee researchers' conclusions, and I am not trying to be a killjoy, but there is something about all this anthropomorphising that stifles enquiry, instead of encouraging it.

If we can let go of the impulse to rank animals, we might find out that our intuition is wrong. And being wrong is one of the most productive things about science. ▮

Marlene Zuk is an evolutionary biologist and author of *Dancing Cockatoos and the Dead Man Test*

No planet B

Don't sweat it quite so much Ten years ago, we feared that catastrophic global warming of between 4°C and 5°C by 2100 was a real risk. Today, that is no longer plausible, says **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

Graham's week

What I'm reading
Waterlog *by wild swimming pioneer Roger Deakin.*

What I'm watching
The new series of Happy Valley *on the BBC.*

What I'm working on
I'm writing a feature about wrinkled skin.

This column appears monthly. Up next week: Annalee Newitz

THE annual ritual of working out where the previous 12 months ranks on the global "hottest-year-on-record" chart is well under way. It was another scorcher, according to a preliminary report by the World Meteorological Organization – probably in fifth or sixth, in which case the past eight years will be the warmest eight on record.

Quelle surprise. As long as we keep on dumping greenhouse gases into the atmosphere, the climate will continue to heat up.

This is obviously alarming news, but, in truth, things aren't as bad as they appear. Don't worry, I haven't fallen down a climate denial rabbit hole. We are still in trouble and need to act quickly. But the fact of the matter is that we are making decent progress. Ten years ago there was a genuine fear that we were heading for catastrophic warming of between 4°C and 5°C by 2100. Today, those worst-case scenarios are no longer plausible.

The story goes back to 2014, when the Intergovernmental Panel on Climate Change (IPCC) published 1184 future greenhouse gas emissions scenarios. To make this baggy monster tractable, the scientists boiled them down to four: one very high scenario, one very low and two in between. The very high one assumed that there would be no climate action whatsoever and that use of fossil fuels would continue on an upward trajectory until 2100. It became known as the business as usual scenario, or BAU.

BAU quickly garnered more scientific and media attention than the other scenarios, in part because it extrapolated the situation at the time, but also because it made for sensational scientific papers and apocalyptic newspaper headlines. A BAU world would have been a "truly catastrophic hellscape of a planet", says climate scientist Zeke Hausfather of NGO Berkeley Earth in California.

In the years since, however, the world has changed dramatically. Progress on renewable energy technology and implementation of climate policies have bent the emissions curve downwards towards warming of around 3°C by the end of the century. Still dangerous, but not hellish. And further progress isn't just possible, but promised. Recent analyses show that, if countries achieve the net-zero pledges that they have already put on the table, warming will stay under 2°C.

> **"The emissions curve has been bent down towards warming of around 3°C by 2100. Still dangerous, but not hellish"**

As a result, the BAU scenario is no longer even remotely plausible, says Roger Pielke, an environmental scientist at the University of Colorado, Boulder. Nor is the next-worse of the four. "It looks like the apocalyptic scenarios, as of today, are off the table," he says.

If anything, says Hausfather, BAU was implausible in the first place. It wasn't just a conservative extrapolation of current trends, but a turbocharged one that assumed, for example, that the use of coal would increase fivefold by 2100, with no climate mitigation action whatsoever.

And yet, the now-obsolete BAU scenario continues to dominate scientific discussions of our climate future. According to a recent analysis by Pielke , the two most recent reports by the IPCC actually increased their emphasis on that worst-case scenario.

This bias is also reflected in scientific journals. An analysis by Pielke's colleague Matthew Burgess found that in the aquatic conservation literature, over 90 per cent of papers published between 2015 and 2022 use the BAU scenario – and about a third use it exclusively. It leaks out into the news media too. "The picture that we paint in terms of science, assessment, journalism and policy is dominated by the most extreme scenario," says Pielke.

This puts climate scientists on the horns of a dilemma. Do they admit BAU was never really that plausible and risk deniers saying "we told you so" and spreading further muck about climate modelling? Or do they keep pushing BAU and risk it becoming obvious they are hawking a straw man, opening the door to… deniers saying "we told you so"?

Honesty is surely the best policy. Deniers are going to deny anyway. Climate scientists arguably have a duty to tell it like it is, and let other people worry about the reaction. In any case, says Burgess – who studies political polarisation around climate issues – deniers are losing, thanks to renewable energy being so cheap and popular.

Perhaps a more pressing danger is that the abandonment of apocalyptic scenarios will send a message that we are out of the woods. We aren't. Aside from the fact that 2°C of warming is dangerous, there are still big unknowns about how the climate system as a whole responds to emissions. The IPCC reckons that even on our current trajectory, we could push warming well over 3°C. If you want a hot tip for 2023, put money on it being in the top nine warmest years on record. ▮

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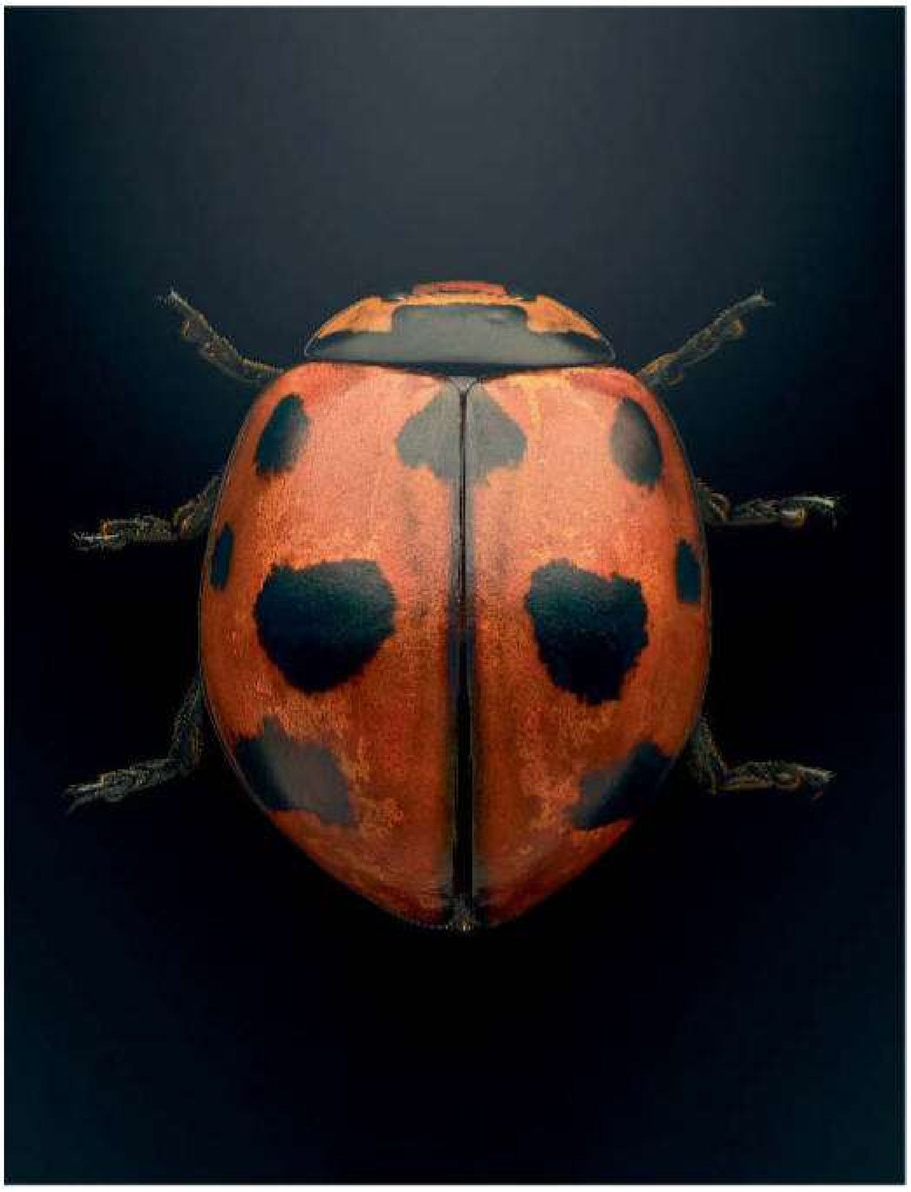

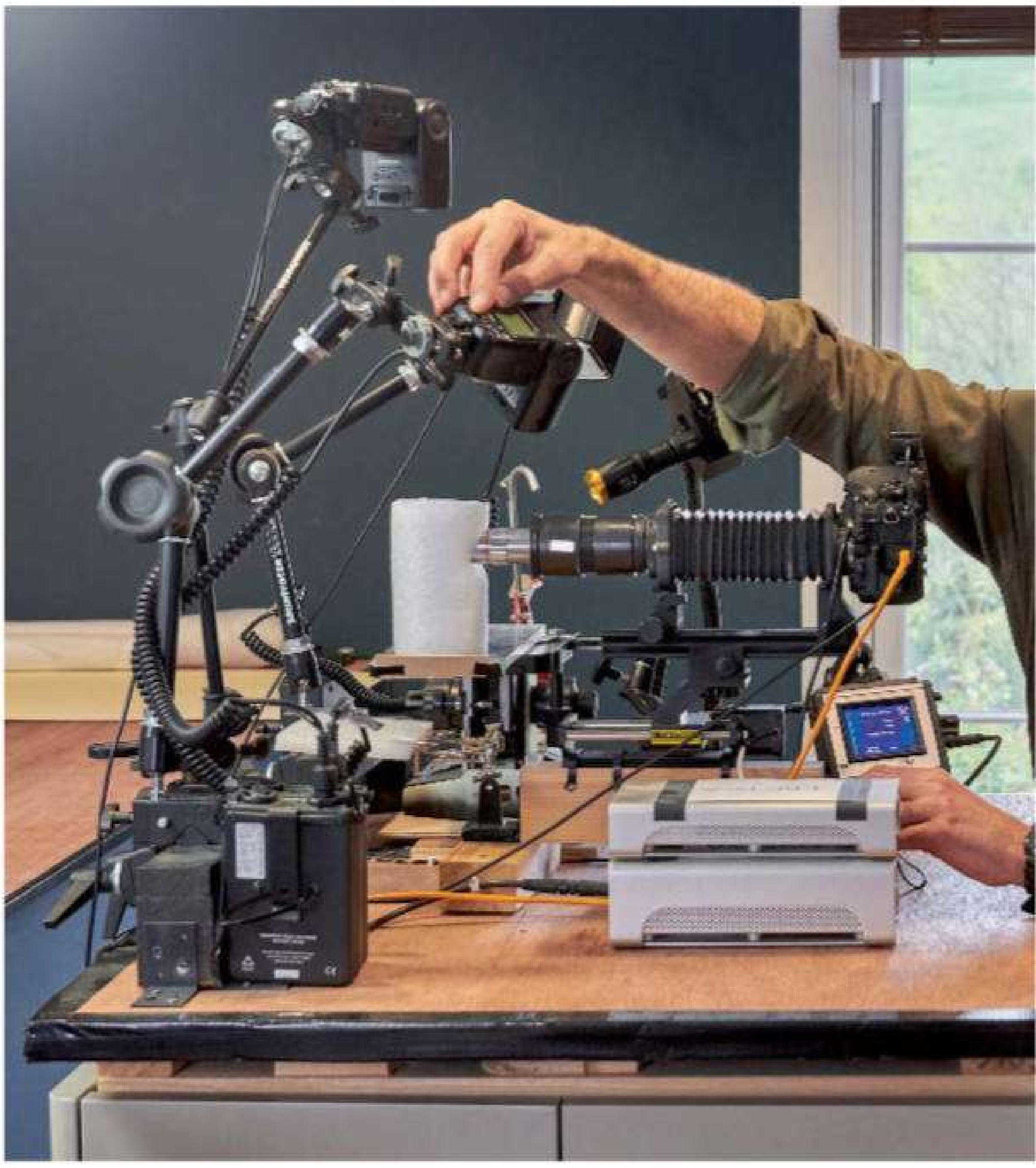

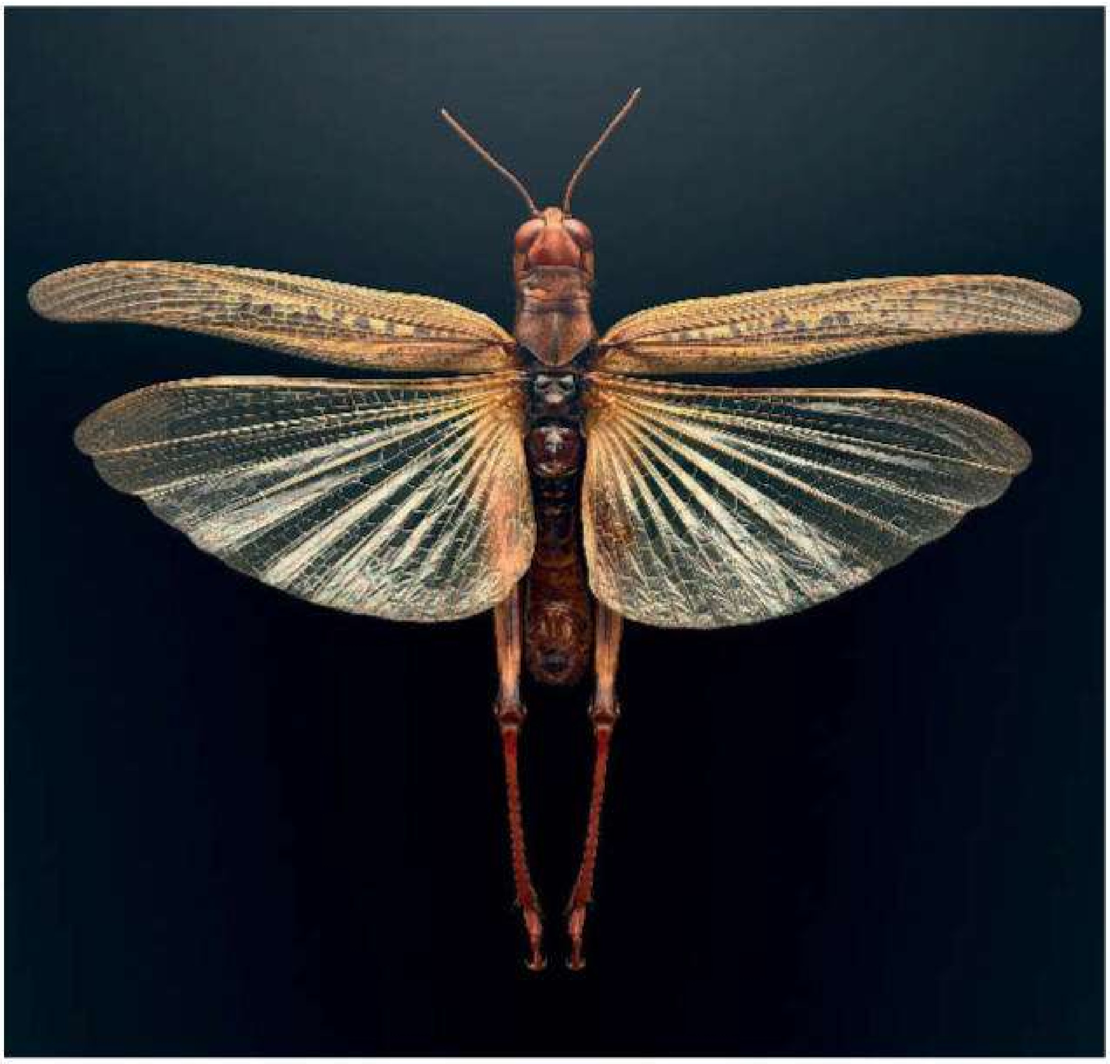

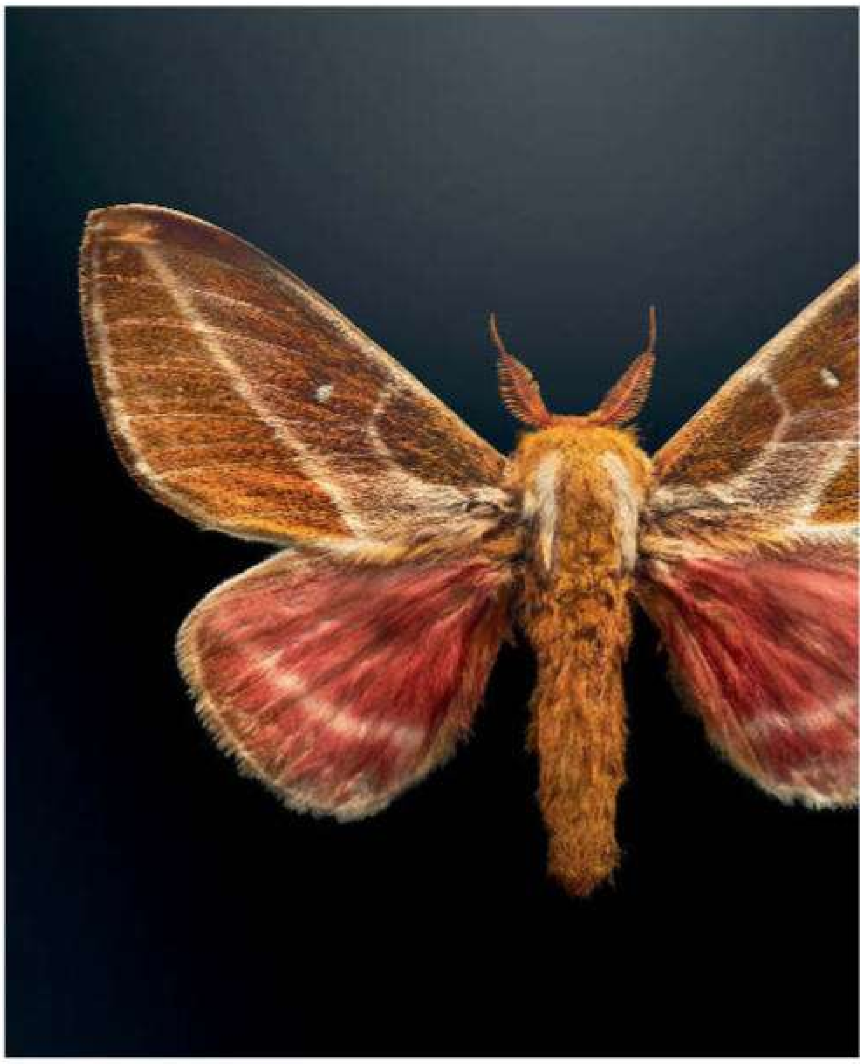

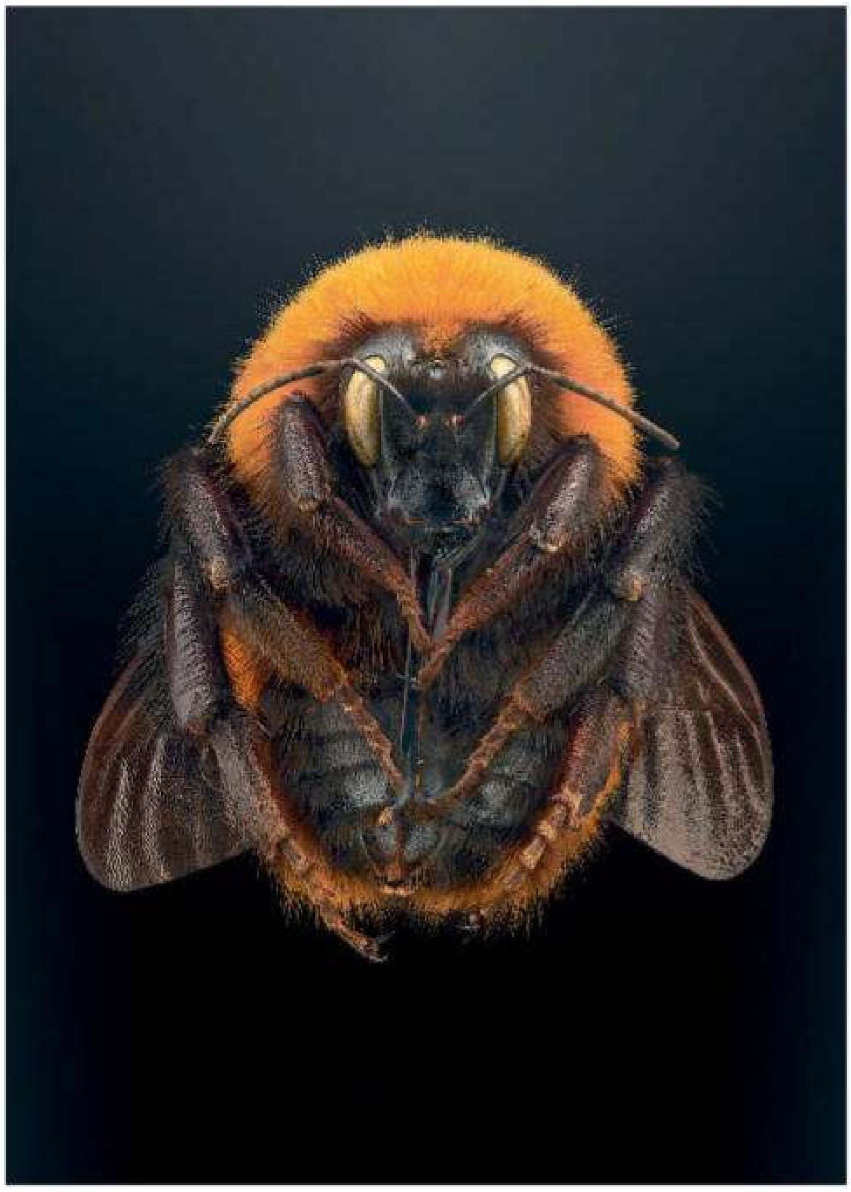

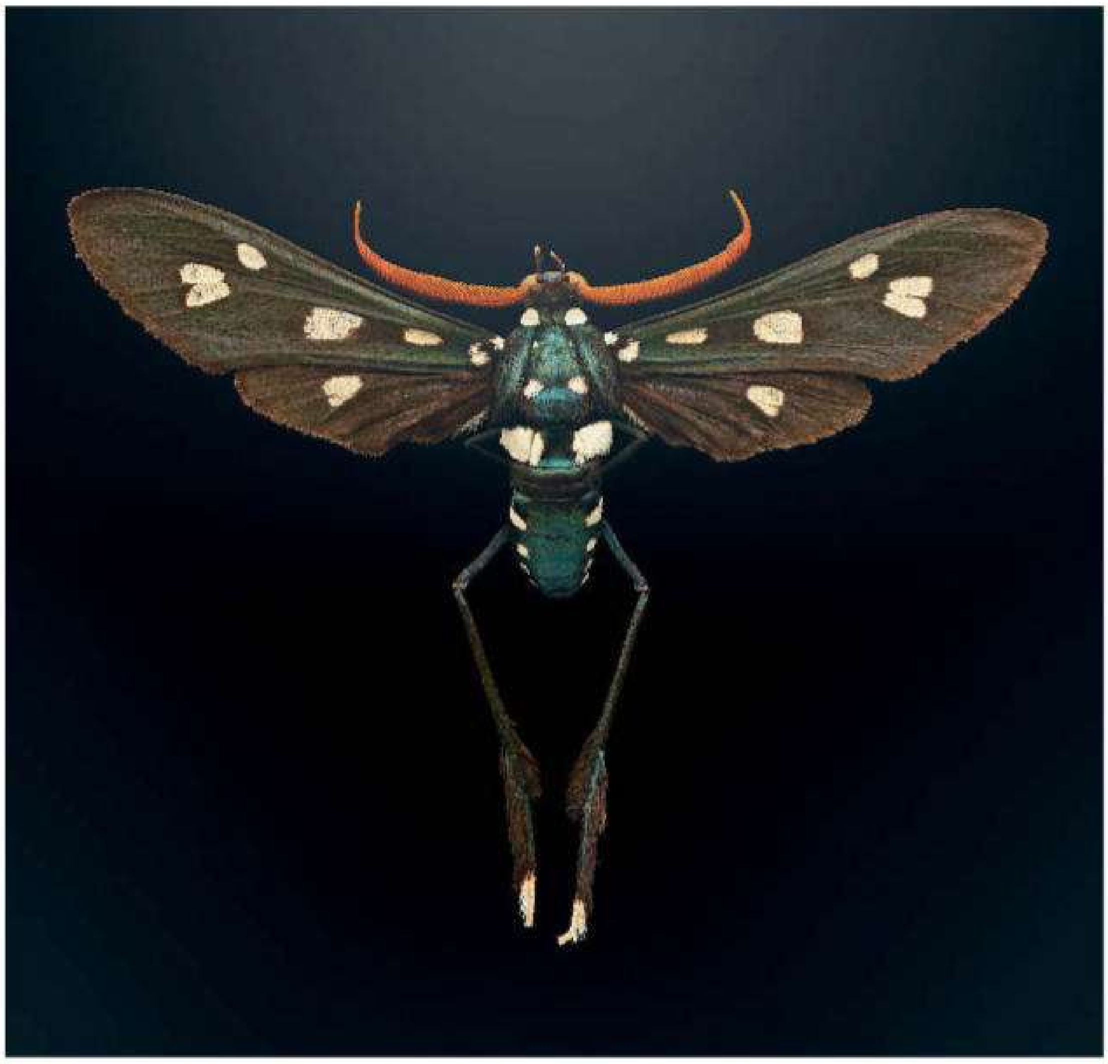

Insects in peril

Photographer **Levon Biss**
American Museum of Natural History/Abrams

WE ARE all aware that our influence on Earth has driven widespread biodiversity loss, from the species that have already disappeared to those on the brink. Among these is a group that outnumbers most other animals, but that we tend to overlook: insects. Some of these are captured here in startling clarity by photographer Levon Biss (pictured), as part of his project *Extinct and Endangered: Insects in peril*.

Biss created 40 vivid portraits of endangered and extinct insect species by combining thousands of shots of specimens from the American Museum of Natural History, New York. He used a photo-stacking technique in which the images, captured via microscope objective lenses on a bespoke photo rig (shown at top centre), are brought together to produce final artworks with extreme levels of detail. The images are currently on display at the museum and feature in a book that shares the project's name.

The top row shows a nine-spotted ladybird (left), numbers of which have been mysteriously declining since the 1980s, and a giant Patagonian bumblebee (right). The only bumblebee native to southern regions of South America, it has suffered from the introduction of domesticated European bumblebees to pollinate crops. The bottom row shows (left to right) the now-extinct Rocky Mountain locust, as well as a raspa silk moth and a lesser wasp moth, both of which are threatened.

Biss says the decline in insect populations is alarming. "Insects provide the foundation of many ecosystems and if critical numbers are lost, then the knock-on effect is immediate and serious."

Gege Li

Editor's pick

Cooking is also great for keeping disease at bay

31 December 2022, p 24

From Drennan Watson, Alford, Aberdeenshire, UK

Michael Marshall's interesting discussion on when human species started to use fire – particularly for cooking food – suggests an increasingly early date. Inevitably, the evolutionary advantages of cooking are raised, focusing on the fact that it significantly increases the digestibility of many foods.

My long years in agriculture lead me to point out another possible reason that fire was adopted early for cooking food: basic sanitation. Cooking kills parasites in foods such as meat. These internal parasites, generally known as foodborne zoonoses, are calculated to still affect 10 per cent of the global population.

Don't let crypto woes derail the blockchain

17/24 December 2022, p 31

From Ian Simmons, Southend, Essex, UK

Annalee Newitz highlights the grim year experienced by big tech, including in the blockchain-based cryptocurrency market. However, there is plenty to cheer about the blockchain, which is essentially a very efficient ledger. Even its critics admit the technology works well.

What we are seeing now is the Perez cycle playing out. This is a pattern identified by economist Carlota Perez. New tech is created, gets hyped and is appropriated by chancers before they are found out or the roof caves in. Then, everyone backs off and the tech is written off. Once the air clears, assuming the tech is sound, mature users adopt it, find a sensible way to use it and go on to build real value.

In 2023, we will see more rational uses of the blockchain grow and, within a few years, it will just be a part of the operating system on which the world runs.

Driverless revolution isn't coming... ever

17/24 December 2022, p 13

From Christian Wolmar, London, UK

Matthew Sparkes correctly assesses the total failure of developing anything like a truly driverless car, yet he still feels compelled to end his piece on a relatively optimistic note.

We have already had over a decade of broken promises, with endless vows that autonomous cars will be available to all in two to three years. You need to examine the obstacles forensically before bandying about statements that claim, for example, that general availability of level 4 cars – those with total autonomy in, say, a city – is "likely to still be more than five years away". Try never instead.

From Dave Neale, Bedford, UK

It is really no surprise that the developers of self-driving cars have at last cottoned on to the difficulties in reaching their objective of total autonomy in all circumstances. It would have been far better for them to target the limited conditions of close-convoy driving on controlled highways such as UK motorways, with communication between cars to ensure they stay close and safe. This is about as simple as it gets and the benefits of reduced congestion by increasing road capacity are enormous.

Gel could be the answer to neutron bomb dangers

17/24 December 2022, p 13

From Alex McDowell, London, UK

Your story on a biogel that could be used in body armour focuses on fending off supersonic bullets.

I think it could do so much more. If used on tanks, it could protect against neutron bombs as well as armour-piercing rounds.

Neutron bombs were proposed as a weapon to use against tanks. They would be detonated above a battalion of these vehicles and the burst of neutrons would penetrate their armour, with lethal effects on the crew. Hydrogen-based materials, such as biogel armour, protect well against neutrons.

Feeding wildlife can do more harm than good

17/24 December 2022, p 72

From Greg Nuttgens, Porthcawl, Bridgend, UK

Your feature on animals that don't move much suggests that, in the case of urban foxes in the UK, this may partly be due to feeding by the public. A look at wildlife-oriented Facebook pages suggests that this practice is indeed widespread. Large-scale artificial feeding of much-loved wild animals like foxes and red kites is unsustainable and damaging to the animals and their ecology, and it should be discouraged.

When it comes to aliens, silence is the right policy

17/24 December 2022, p 64

From Geoff Harding, Sydney, Australia

I agree we should be far more cautious in unilaterally trying to communicate with aliens, on the grounds that they have apparently been far more circumspect in communicating with us.

Arguably, the probability of intelligent life evolving elsewhere long before we did is high, but our most sensitive telescopes have detected nothing that proves its existence. Maybe extraterrestrials agree with the 98 per cent of astronomers surveyed over a decade ago, who urged caution. Aliens may have learned by bitter experience that communication isn't worth the risk.

Universal, swappable car batteries are a non-starter

Letters, 17/24 December 2022

From Martin van Raay, Culemborg, The Netherlands

Regarding Sue Cannon's idea of quick-change batteries to get electric vehicles "refuelled" rapidly: Renault looked into the use of interchangeable batteries for modern cars, but abandoned it, though the company now appears to be entertaining the idea again. Nio (another manufacturer) has plans to use swappable batteries.

The problem with this idea is that no single car maker can build swapping stations globally. They would have to cooperate, which would mean standardisation in chassis design between firms. I don't see that happening.

Does the delete key also wipe magnetic memory?

17/24 December 2022, p 66

From Mark Tapley, Woldingham, Surrey, UK

I very much enjoyed the article about cloud companies' storage of material on magnetic tape. However, the story of Google accidentally deleting emails from Gmail accounts and then restoring them from the magnetic tape archives made me think.

What about that embarrassing photo of me with long hair, a kipper tie and flares uploaded to an Apple iCloud account? If it was deleted on the cloud, would it still be on Apple's magnetic tapes? Do these companies scrub the tape too when we delete our content?

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT will be delayed

For the record

In our look at magnetic tape (17/24 December 2022, p 66), the 1970s IT storage system shown was a disc drive.

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Worth paying attention to

Gloria Mark has studied distraction since 2004. Her first book is a welcome injection of evidence into the issue of declining attention spans, says **Elle Hunt**

Book
Attention Span
Gloria Mark
William Collins

JUSTIN PAGET/DIGITAL VISION/GETTY IMAGES

How can we balance work and well-being in today's tech-dependent world?

MANY of us have some sense of what an "attention span" is. We may even be quietly convinced that ours is shorter than it used to be. The idea that it is harder to concentrate today than it was in the past is insidious, supported by anecdotal evidence – and probably our own experience – of being distracted by our personal devices, as well as creeping disquiet about our mounting reliance on technology in general.

Stolen Focus: Why you can't pay attention by Johann Hari was one of the top-selling non-fiction books of last year. In it, Hari blamed our fragmented attention on "powerful external forces", predominantly tech giants, and called for a society-wide "rebellion" to reclaim it.

This response reflects the mainstream interest in the issue – not to mention the concern. But as Hari acknowledges (more than halfway through the book), there are, in fact, no long-term studies tracking attention spans over time, so we have no way of knowing whether technology has indeed caused our powers of concentration to deteriorate.

Gloria Mark's first book, then, is a welcome injection of evidence, nuance and pragmatism into the discussion. Mark, a cognitive psychologist and professor of informatics at the University of California, Irvine, has been studying human-computer interaction since the mid-1990s, and distraction in particular since 2004. In *Attention Span*, she brings together the findings from her peer-reviewed scientific research with conclusions as to how they might be applied to find "focus for a fulfilling life".

Over 15-odd years, Mark has empirically tracked patterns of "attention-switching", showing how our focus roams about – between the physical world and the digital one, but also from task to task on our devices.

> **"In one study, Gloria Mark found that participants checked their email 77 times a day on average"**

In 2004, when Mark conducted her first study on a range of office workers, she found that, when at work on a screen, they changed their attention every 2.5 minutes. By 2016, that was down to 47 seconds, where it has stayed.

These were time-intensive and, as such, often small-scale studies (of around 1500 people total, Mark estimates), itself proof of how challenging it is to extricate ourselves from screens, even for the purpose of research.

It took Mark six years to find an organisation willing to let her restrict access to email to some of its employees to assess its impact. She found a clear-cut case in favour of shutting it off, with reduced stress and attention-switching (which are related), and also a social benefit, as colleagues made the effort to communicate with each other in person. In another study, Mark found that participants checked their email 77 times a day on average. "Experiencing interruptions all day, every day, can certainly take its toll in terms of more drained resources and increased stress – a high cost," she writes.

Another treatment of the subject could have been fearmongering or fatalistic about our future with tech, but Mark is even-handed and generally optimistic about our chances of taking back control of our devices and attention. It starts, however, with more realistic expectations.

In *Attention Span*, she dismantles misconceptions, such as that all time-wasting on screens is negative, or that we should always be aspiring to be focused or in psychological "flow" (as championed by Hari) when at work on a computer.

Instead, Mark advises cultivating awareness of our own individual rhythms of attention and structuring days so that work demanding concentration or creativity aligns with peaks of focus, while less intensive tasks are planned for when we are at an ebb.

In focusing on practical strategies rather than silver-bullet or short-term solutions like "digital detoxes", *Attention Span* is a valuable guide to how to balance work and well-being in a world increasingly dependent on tech. Mark also emphasises the need to take breaks: instead of your phone stealing your attention, it could be that you are simply exhausted.

Though technology may enable us to be more productive, our cognitive resources are limited, says Mark. Part of reclaiming our attention may be accepting we must simply attempt less. ▮

Elle Hunt is a writer based in Norwich, UK

A window on the past

This is a gripping look at palaeobiology, a field achieving incredible insights into ancient life on Earth, finds **Simon Ings**

Book

Remnants of Ancient Life

Dale Greenwalt

Princeton University Press

WHAT is a fossil made of? Mineralised rocky fossils are what first spring to mind, but others, like the fossils of the Burgess Shale in Canada, are made of pure carbon and can be thought of as proto-coal. There are also tantalising Cretaceous insects preserved in amber.

Whatever they are made of, fossils contain treasures. The first really good microscopic study of mineralised dinosaur bone was able to reveal its internal structure, and was written up in 1850 by British palaeontologist Gideon Mantell.

Still, classifying fossil organisms on the basis of their structure and location seemed to be virtually the only weapon in the palaeobiologist's arsenal until 1993. That was the year the field erupted, as ancient pigments, proteins and DNA were detected (not too reliably at first) in rock and all manner of other fossil substrates: a foundational moment that was captured more or less as it happened by Michael Crichton's novel *Jurassic Park*.

Crichton's blood-sucking insects fossilised in amber were a bust in real life. But the author of *Remnants of Ancient Life: The new science of old fossils* – a dull title for this vivid, gripping book – has since extracted traces of ancient haemoglobin from the stomach of a fossilised mosquito, so never say die.

Dale Greenwalt, who spends 11 months of the year "buried deep in the bowels" of the Smithsonian's National Museum of Natural History in Washington DC, has written a riveting account of a field achieving revolutionary insights. The finds he cites are extraordinary enough: a cholesterol-like molecule found in a 380-million-year-old crustacean and the discovery of the biopolymer chitin in the exoskeleton of a fossil from the 505-million-year-old Burgess Shale, to name just two.

More interesting are the inferences we can draw about the physiology, behaviour and evolution of the organisms these molecules came from. Valuable insights can even come from traces that are fragmented, degraded and condensed, says Greenwalt. It is even possible to calculate and construct hypothetical "ancestral proteins" and, from their study, argue strongly that life on Earth originated in deep ocean vents.

The story of biomolecules in palaeontology has its salutary side. Brilliant innovators have had to learn the limitations of their new techniques and return, as often as not, to the insights of comparative anatomy to confirm and calibrate their work. The polymerase chain reaction (PCR) technique is the engine powering our access to ancient DNA sequences, but it had teething problems, including the publication of a DNA sequence thought to be from a 120-million-year-old weevil that actually belonged to a modern fungus.

More problematic are the cul-de-sacs. For instance, plant proteins only last for about 30,000 years, so the revolution currently shaking up palaeobiology seems to have left the botanists high and dry.

Greenwalt sets many wonders against these setbacks, though. And there is a further twist in his tale: it may become possible to classify plants and microbes based on the repertoire of small biomolecules they leave behind.

"The biomolecular components of plants have been found as biomarkers in rocks that are two and a half billion – with a 'b'! – years old," says Greenwalt. Given that the 3.7-billion-year-old cyanobacteria that produced the stromatolites (layered mounds of sediment made by microorganisms) in Greenland are the same age as the rocks of Mars's Gale crater, "Are authentic ancient biomolecules on Mars so implausible?" asks Greenwalt.

His day job may keep him in the Smithsonian's basement, but this researcher's gaze is set firmly on the stars. ▮

Simon Ings is a writer based in London

The palaeontology collection at the Smithsonian's National Museum of Natural History

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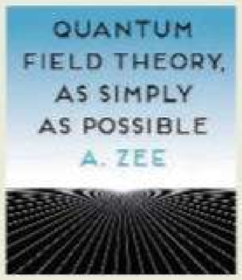
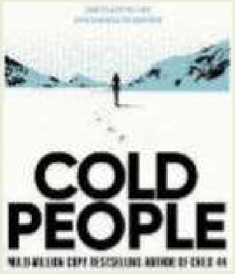


Read

Quantum Field Theory, As Simply As Possible is delivered with humour and erudition by Anthony Zee. What better way to get the little grey cells going than by unifying quantum mechanics and special relativity? On sale from 17 January.

Watch

Hearing the Light is a talk by Clara Brasseur about representing telescope data as sound, also called astronomical data sonification. Listen to real data from the Kepler Space Telescope (pictured) in her online talk on 20 January at 7.30pm GMT.



Read

Cold People struggle to colonise Antarctica following a mysterious invasion in Tom Rob Smith's high-concept thriller. Can we adapt fast enough to ensure our species' future in the freezing cold? On sale from 19 January.

NASA/JPL-CALTECH

The games column

What to play in 2023

From exploring the world of *The Expanse* to *Starfield,* a sci-fi role-playing game set in the 24th century, there is much to look forward to this year. Let's just hope there are no more delays, says **Jacob Aron**

Jacob Aron is *New Scientist*'s news editor. Follow him on Twitter @jjaron

QUANTIC DREAM

Delve into the depths of an underwater abyss in *Under the Waves*

Game

Under the Waves
Parallel Studio
PC, PlayStation 4 and 5, Xbox One and Series X/S

Atomic Heart
Mundfish
PC, PlayStation 4 and 5, Xbox One and Series X/S

The Expanse: A Telltale Series
Telltale Games
PC, PlayStation 4 and 5, Xbox One and Series X/S

Pragmata
Capcom
PC, PlayStation 5, Xbox Series X/S

Marvel's Spider-Man 2
Insomniac Games
PlayStation 5

Senua's Saga: Hellblade II
Ninja Theory
PC, Xbox Series X/S

IF YOU have read this column over the past few years, you will know that the pandemic has had a huge impact on the video game industry, as titles have been delayed by supply chain shortages and by developers scrambling to work from home. The new generation of consoles – the PlayStation 5 and Xbox Series X/S – launched in 2020, but arguably it feels like we are still in the past, with few games taking advantage of the new hardware.

Could 2023 be the year this changes? Possibly. Looking ahead to some of the titles I am excited about, I could easily fill this list with games from my 2022 preview article. There is *Stalker 2: Heart of Chernobyl*, set in the Chernobyl exclusion zone, which was delayed when its Ukrainian developers had to contend with Russia's invasion, or *Starfield*, a sci-fi role-playing game set in the 24th century. Both are big, open-world games being released exclusively on PC and the new Xbox, so they should look pretty impressive, but I wouldn't be surprised if more delays are on the cards.

There are other games I am looking forward to, though, even if they are also being released on old hardware. *Under the Waves* looks like a creepy opportunity to explore the deep sea in a submarine. The trailer doesn't give much away, but I am intrigued by what looks like a flying drone inside an underwater base, given that the game is apparently going to be set in the 1970s.

> **"In *Pragmata*, an astronaut-like figure explores a New York City street that seems to be taken over by aliens"**

Sticking with the retro-futuristic theme, *Atomic Heart* is a first-person shooter set in an alternative mid-20th century Soviet Union, where robots allowed Stalin to defeat Nazi Germany earlier than in reality. I am slightly wary of how it will feel to play the game amid the ongoing conflict in Ukraine, however, since it is created by Russian developer Mundfish and is dripping with Soviet iconography.

Perhaps it would be best to move swiftly on to games set in the future, such as *The Expanse: A Telltale Series*. It is adapted from the sci-fi TV show of the same name, which, in turn, is adapted from a series of novels. I actually preferred the books to the live-action version of the story, which I found a bit of a slog at times, but I am interested in exploring the world of *The Expanse* for myself.

Another sci-fi game I have my eye on is *Pragmata*. Again, we don't know much, but the trailer is intriguing: an astronaut-like figure explores a New York City street that seems to have been taken over by aliens. There is also a young girl and a cat that might both be holograms. Oh, and the whole thing takes place on the moon? I am keen to know more…

The first of two sequels on my list is *Marvel's Spider-Man 2*. Sony used the 2018 original to demonstrate the power of the PlayStation 5 by letting you zip around Manhattan with almost no loading time, so I am expecting the sequel to be a technical marvel.

Finally, there is *Senua's Saga: Hellblade II*. When I reviewed the first game in the series, *Hellblade: Senua's Sacrifice*, I praised its approach to portraying the main character's psychosis, in an unusual video game treatment of mental health.

Developer Ninja Theory has been working with psychiatrists to study whether games can be used to measure or modify people's state of mental distress, and it will be fascinating to see if that research has made it into the sequel. All in all, there is a lot to look forward to. ▮

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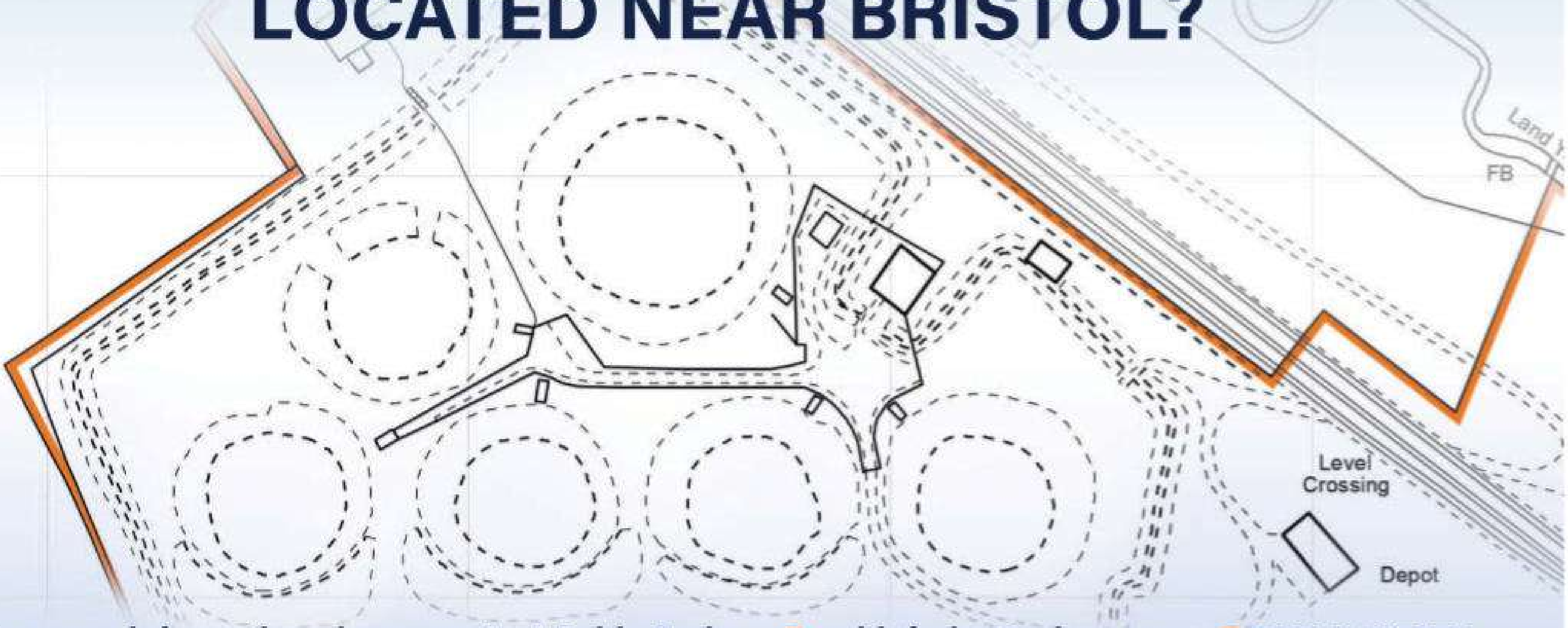

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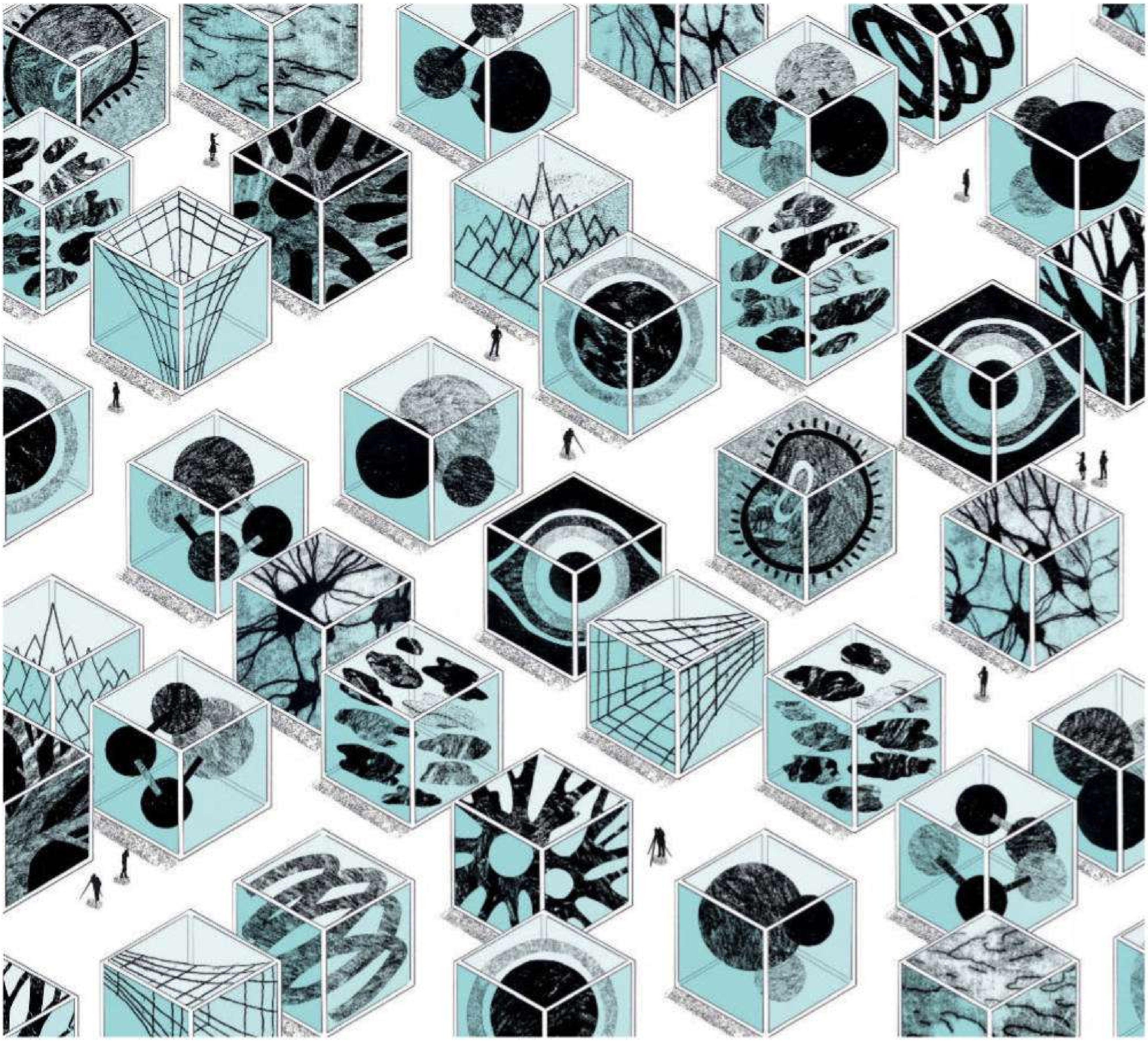


JAMIE MILLS

The limits of knowledge

WHAT came before the big bang? How do our minds work? Can we know the future? Our understanding of the universe and everything in it has reached stupendous heights, but plenty of questions remain beyond us. There are things we don't know, things we will never know and things we can't even imagine. Over the next seven pages, we will explore five key obstacles to our ongoing pursuit of knowledge – and get a better grip on what knowledge really is.

Limit 1
When measurement is impossible

MOST of us intuitively feel that reality ought to exist just fine on its own when we aren't looking. If a tree falls in a forest when no one is around to hear the crash, the air still vibrates with sound waves, right? Yet it is a tricky proposition to prove and one that gets more slippery when you consider things that seem to exist, but that we will never be able to observe. Grappling with the question of how to measure the immeasurable can, however, help us see what reality is truly like.

There are a few realms where the laws of nature themselves forbid us from treading. Nothing can travel faster than the speed of light, which means we will never see beyond the edge of the observable universe – the maximum distance that light can have traversed to reach our telescopes since the beginning of the universe. General relativity rules that nothing within a black hole can escape, so that is another no-go zone (see "What is inside a black hole?", page 41).

But perhaps the most fundamental limit to what we can measure comes from the laws of quantum physics. These tell us that if we measure some property of a quantum particle today, it is impossible to know if we will get the same result when measuring it with an identical set-up tomorrow. In this sense, the laws of quantum mechanics aren't like Isaac Newton's classical laws of motion, which give definite predictions (see "When things are outrageously complicated", page 40). Instead, they can only predict how stuff behaves on average.

The traditional interpretation of these facts is that particles exist in a cloud of many possible states at once, described by a mathematical construct known as a wave function. The idea is that the wave function only collapses into a single state, to certainty, upon measurement. If so, before we look at it, reality is a kind of fog of possibilities and our knowledge of it is blurry at best.

But not everyone agrees with that. For Vlatko Vedral, a physicist at the University of Oxford, it is a mistake to make a distinction between a particle that adheres to the rules of quantum theory and the observer or measurement apparatus that follows the laws of classical physics. He reckons that, ultimately, everything is quantum and we should see reality as one gigantic, universal wave function.

If we accept that wave functions are the essence of reality, this casts quantum physics in a new light. Everything has a wave function and all of them are quantum entangled with each other, meaning a measurement of one affects the others. So we can't think about measuring isolated objects in the traditional scientific sense because the measurement apparatus and the object being measured always interact. In other words, reality as we see it is a product of both the observer and the object under scrutiny, rather than some stand-alone real view of that object, which seems beyond us. "You can only ever isolate systems imperfectly," says Noson Yanofsky at Brooklyn College in New York. "That leads to a lack of knowledge." Whether this is really a limitation, though, depends on your point of view. "It's only a limitation if you're thinking in terms of these old concepts," says Vedral.

Many physicists would agree that drawing a clear line between small quantum objects and larger classical ones is problematic. But opinions differ on precisely how to interpret the quantum realm. Carlo Rovelli at Aix-Marseille University in France doesn't think the wave function is a real object. He has been working on an alternative idea known as the relational interpretation of quantum mechanics. In this view, everything in existence exists only in relation to other things, including you. A particle is there when you measure it, but doesn't exist at all times. "To ask what an electron's momentum is can simply be a meaningless question," he says.

We may never prove which interpretation is right, because our observations of the quantum world seem to change it. But there may be ways to progress. Rovelli argues that we can use the different interpretations to clarify existing puzzles in physics. For instance, he suspects that his relational view could help align the two famously incompatible pillars of modern physics: quantum theory and general relativity. If it does, that is a good reason to favour it.

Then there is the possibility – albeit a slim one – that one day we will find a way of seeing into the quantum fog without collapsing the wave function. If the laws of physics say something is impossible, that is only valid as long as the laws themselves hold. A deeper version of quantum theory could come along and make the impossible possible. But Vedral isn't holding his breath that a definite, predictable world will reappear. "It's probably going to be even weirder," he says. **Thomas Lewton**

"A deeper version of quantum theory could make the impossible possible"

Limit 2

When things are outrageously complicated

EVERYONE knows it is impossible to predict the future, but not a lot of people pause to wonder why. Even putting aside the issue of free choice, it isn't straightforward. After all, Isaac Newton's laws of motion can be used to calculate what any object will do if we know its starting trajectory and the forces acting on it. French thinker Pierre-Simon Laplace once imagined a being armed with these laws and a lot of information, writing that "for such an intellect, nothing would be uncertain and the future, just like the past, would be present before its eyes".

The reason the world still unfolds in a cascade of the unexpected is that there is a gulf between what equations can predict in theory and what it is possible to calculate in practice. The limits of our technology, the speed of our computers and the incredible complexity of nature all mean that some things are practically impossible to know.

One problem is that the things we want to study are sometimes composed of many objects that mutually affect each other. So while we can predict the path of a flying football just fine, we can't do the same with particles because there are usually lots of them flying around, all exerting forces on each other. It is beyond our current computing abilities to simulate all those interactions at once – with any more than about 10 particles, we don't stand a chance.

Complexity is a problem in many fields of science, not least medicine. Take proteins, the long strings of amino acid molecules that fold themselves up into intricate shapes inside our bodies to do all manner of jobs, from powering our metabolism to fending off bacteria. We know what forces and considerations dictate the functional, folded shape each protein will adopt. But there are so many atoms interacting with each other that we can't compute this perfectly. This is a frustrating limit to our knowledge, because knowing the precise structure of a protein can help us design new drugs.

There is an even more fundamental issue at play. It turns out that the behaviour of some systems are sensitive to even the tiniest difference in starting conditions – they are subject to what we call chaos. The weather is a classic example. Small changes in air temperatures or moisture levels on one day can result in unpredictable storms the next. Chaos applies to apparently simpler scenarios too. The roughly 27-day orbit of the moon around our planet varies erratically by up to 15 hours from month to month due to the constantly shifting pull the moon feels from Earth and the sun.

Chaos and complexity certainly put limits on what we can know. But they are more malleable than the iron-clad boundaries dictated by physical laws themselves (see "When measurement is impossible", page 39). For example, by measuring atmospheric conditions in the present more precisely and using faster computers, we can make better weather forecasts, up to a point.

Storms can still surprise forecasters

NASA

While aspects of the world – from weather to financial markets to the patterns of disease spread – will always be subject to chaos, there are tricks we can pull to understand them better. One helpful strategy, says physicist Tim Palmer at the University of Oxford, is to run a large series of simulations of the system you are studying with tiny variations in your starting conditions. The sooner the outcomes of the scenarios begin to diverge, the more unpredictable the system is. These "ensemble simulations" are now a standard

On the edge

Over the next few pages, we explore five questions that take us to the outer limits of knowledge

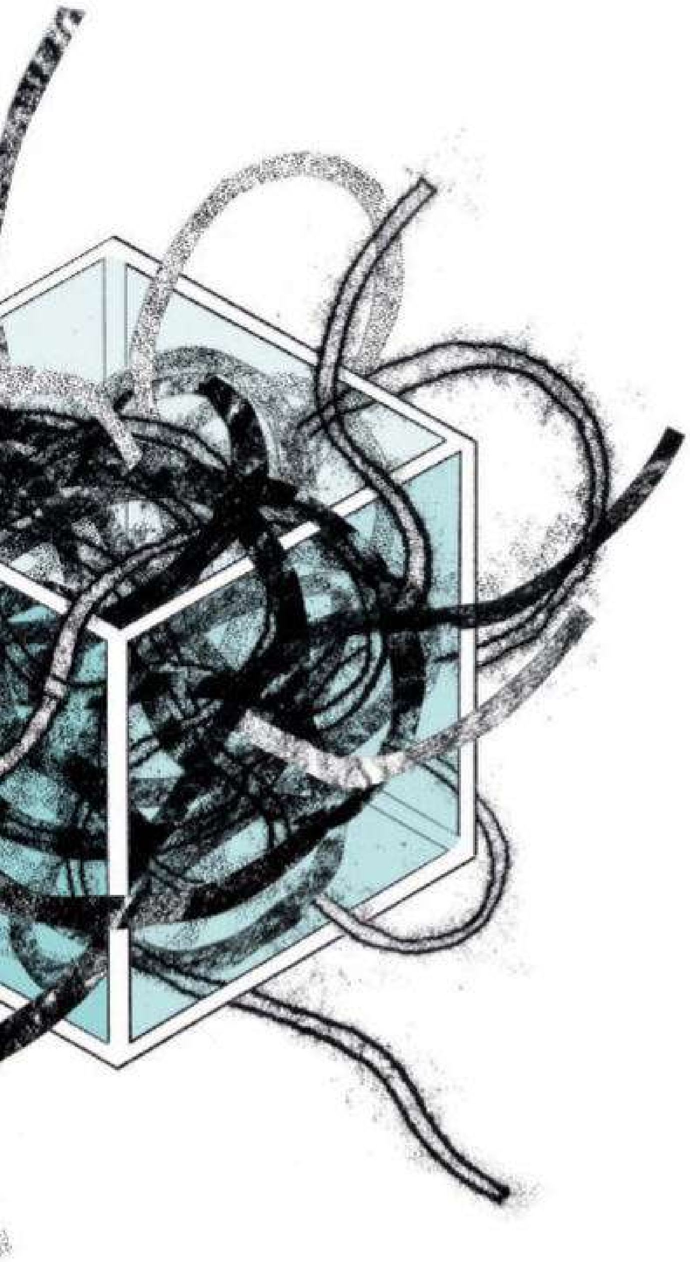
WILL WE EVER BUILD A WARP DRIVE?

Most spacecraft use propulsion systems. But there might be another way to zip around: by warping the space around you. Think of it like swimming breaststroke, where you scoop up water in front of your body and push it backwards. Could we ever build an engine that does this in space?

Everything with mass warps space-time to some extent. The appeal of a warp drive is that, in theory, it could effectively move faster than light. To do that, however, it would have to be so massive that it would form a black hole. There is a workaround, proposed by physicist Miguel Alcubierre: use something with negative mass. This would warp space-time without creating a black hole. There are good reasons to think objects with negative mass can't exist, but the laws of nature don't rule them out. The upshot is that a useful warp drive will probably – but not definitively – never be possible.

approach. This is why rain forecasts now often come with a percentage chance attached – helpful for giving us an appropriate level of confidence in leaving our umbrellas at home. "Enlightened ignorance is often characterised as knowing what you don't know," says philosopher James Ladyman at the University of Bristol, UK.

But it doesn't necessarily have to be this way. A case in point is the way that artificial intelligence (AI) has revolutionised our ability to calculate the structures that proteins adopt. Deep-learning AIs don't attempt to crack this by modelling the physics. Instead, they are trained on thousands of known protein structures and use this knowledge to predict new ones. In July 2022, AI firm DeepMind said that its AlphaFold algorithm had calculated the structures of 200 million proteins, nearly all of those known to science. Sometimes, the limits of what it is practically possible to fathom can change drastically in a blink. **Anna Demming**



Limit 3

When our best tool to describe the universe may be unreliable

YOU might think that mathematics is the most trustworthy thing humans have ever come up with. It is the basis of scientific rigour and the bedrock of much of our other knowledge too. And you might be right. But be careful: maths isn't all it seems. "The trustworthiness of mathematics is limited," says Penelope Maddy, a philosopher of mathematics at the University of California, Irvine.

Maddy is no conspiracy theorist. All mathematicians know her statement to be true because their subject is built on "axioms" – and try as they might, they can never prove these axioms to be true.

An axiom is essentially an assumption based on observations of how things are. Scientists observe a phenomenon, formalise it and write down a law of nature. In a similar way, mathematicians use their observations to create an axiom. One example is the observation that there always seems to be a unique straight line that can be drawn between two points. Assume this to be universally true and you can build up the rules of Euclidean geometry. Another is that 1 + 2 is the same as 2 + 1, an assumption that allows us to do arithmetic. "The fact that maths is built on unprovable axioms is not that surprising," says mathematician Vera Fischer at the University of Vienna in Austria.

These axioms might seem self-evident, but maths goes a lot further than arithmetic. Mathematicians aim to uncover things like the properties of numbers, the ways in which they are all related to one another and how they can be used to model the real world. These more complex tasks are still worked out through theorems and proofs built on axioms, but the relevant axioms might have to change. Lines between points have different properties on curved surfaces than flat ones, for example, which means the underlying axioms have to be different in different geometries. We always have to be careful that our axioms are reliable and reflect the world we are trying to model with our maths.

The gold standard for mathematical reliability is set theory, which describes the properties of collections of things, including numbers themselves. Beginning in the early 1900s, mathematicians developed a set of underpinning axioms for set theory known as ZFC (for "Zermelo-Fraenkel", from two of its initiators, Ernst Zermelo and Abraham Fraenkel, plus something called the "axiom of choice").

ZFC is a powerful foundation. "If it could ›

WHAT IS INSIDE A BLACK HOLE?

If you fall into a black hole, you aren't coming back. That goes not just for people, but any measuring device or unfortunate craft we might send into the void. Past the black hole's iconic event horizon, gravity becomes so strong that objects are "spaghettified". Still, there might be a loophole by which something can come back out.

Decades ago, Stephen Hawking figured out that black holes slowly evaporate by emitting radiation. If a black hole evaporates entirely, then the information it had absorbed over the aeons would have been obliterated – but a key law of nature is that information can't be destroyed. This is the essence of the black hole information paradox.

Physicists remain sharply divided on what to make of it. We have photographed black holes, modelled them using exotic fluids here on Earth and chipped away at the problem theoretically. Still, the goal is that by studying what happens right at the edge of the event horizon, we can inch closer to solving it. In the process, many hope we might get a glimpse of a new theory of quantum gravity, one that surpasses both quantum mechanics and general relativity.

be guaranteed that ZFC is consistent, all uncertainty about mathematics could be dispelled," says Maddy. But, brutally, that is impossible. "Alas, it soon became clear that the consistency of those axioms could be proved only by assuming even stronger axioms," she says, "which obviously defeats the purpose."

Maddy is untroubled by the limits: "Set theorists have been proving theorems from ZFC for 100 years with no hint of a contradiction." It has been hugely productive, she says, allowing mathematicians to create no end of interesting results, and they have even been able to develop mathematically precise measures of just how much trust we can put in theories derived from ZFC.

In the end, then, mathematicians might be providing the bedrock on which much scientific knowledge is built, but they can't offer cast-iron guarantees that it won't ever shift or change. In general, they don't worry about it: they shrug their shoulders and turn up to work like everybody else. "The aim of obtaining a perfect axiomatic system is exactly as feasible as the aim of obtaining a perfect understanding of our physical universe," says Fischer.

At least mathematicians are fully aware of the futility of seeking perfection, thanks to the "incompleteness" theorems laid out by Kurt Gödel in the 1930s. These show that, in any domain of mathematics, a useful theory will generate statements about this domain that can't be proved true or false. A limit to reliable knowledge is therefore inescapable. "This is a fact of life mathematicians have learned to live with," says David Aspero at the University of East Anglia, UK.

All in all, maths is in pretty good shape despite this – and nobody is too bothered. "Go to any mathematics department and talk to anyone who's not a logician, and they'll say, 'Oh, the axioms are just there'. That's it. And that's how it should be. It's a very healthy approach," says Fischer. In fact, the limits are in some ways what makes it fun, she says. "The possibility of development, of getting better, is exactly what makes mathematics an absolutely fascinating subject." **Michael Brooks**

Limit 4
When we can't directly experience something

IMAGINE a woman who has somehow been brought up from birth inside a black, white and grey room, so everything she sees is in monochrome. Yet imagine also that she has spent her life studying the science of colour. She learns how different wavelengths of light are perceived by the eye, how a prism separates white light into a spectrum and so on – but has never personally seen anything other than shades of black or white. Now, imagine that she leaves the room for the first time and sees the vibrant palette of the real world. Most of us would agree that, at that moment, the woman learns something new about colour.

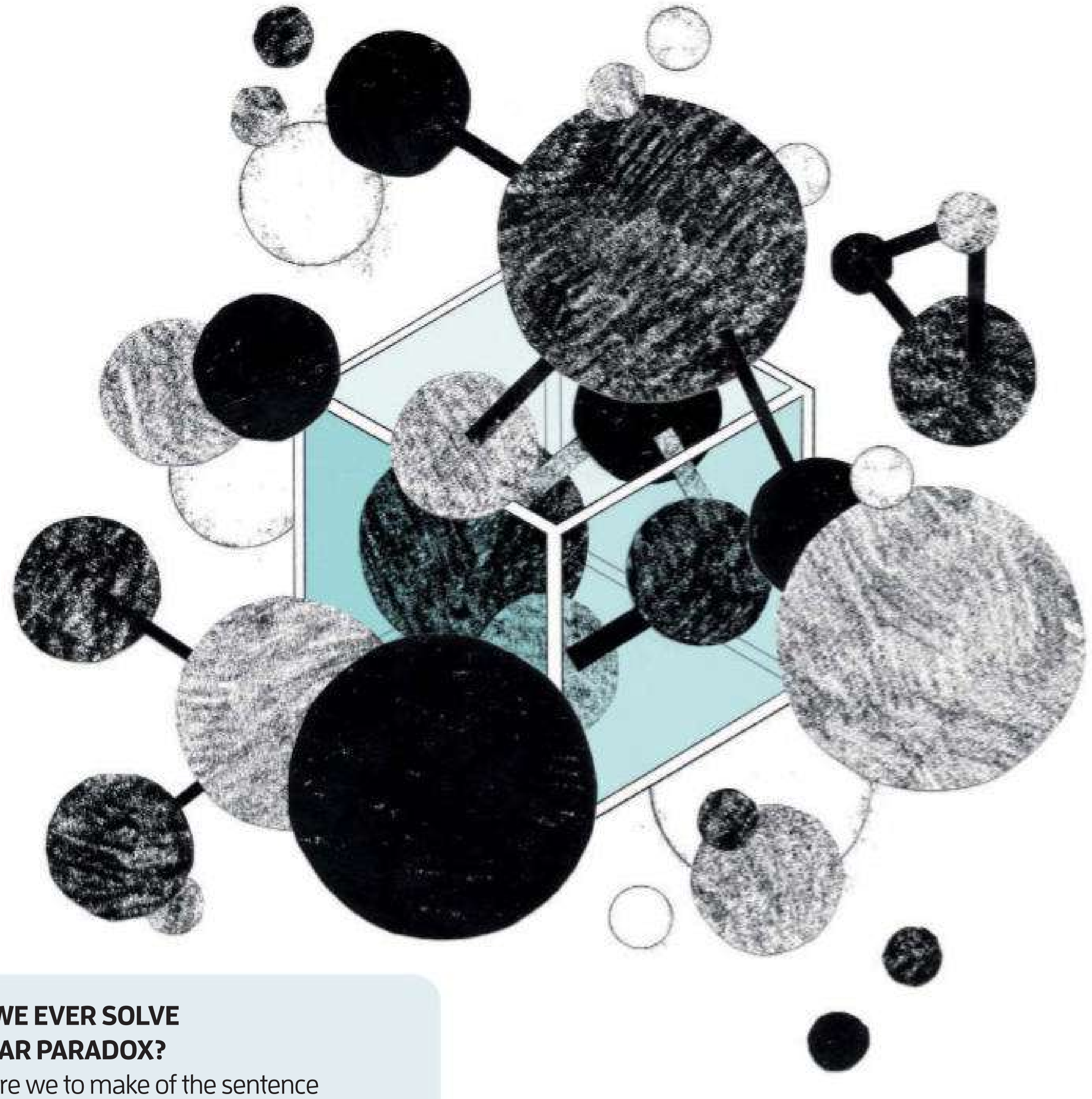
This thought experiment, proposed by philosopher Frank Jackson in 1982, was intended to argue against physicalism, the belief that there is nothing over and above the physical universe. But it also suggests that there are types of knowledge that can't be gained by reading, measuring or deducing. They have to be learned through direct experience.

The impossibility of sharing someone else's subjective experiences has consequences for the world of medicine. It makes it harder to know what is going on when someone has hallucinations, for instance, or to know how

It is hard to put the experience of colour into words

DAVE TACON/POLARIS/EYEVINE

“There is no way to know if one person’s ‘ache’ is another person’s ‘agony’ ”



much pain someone is in. We rely on their descriptions, with no way to know if one person’s “ache” is another’s “agony”. “It is impossible for me to feel your pain,” says Stephen Law, a philosopher at the University of Oxford. “The idea is that the mind is a private world, hidden behind a kind of super barrier. It isn’t a physical barrier like your skull, because even if we could physically get inside your head, it is impossible for us to breach it.”

Another consequence of this limit on knowledge is that we can never know if our perceptions of the world are the same as those of someone else. There is much experimental evidence showing that people can have different experiences of particular colours, sounds, smells and so on. This isn’t just because their sense organs may have slight physical differences, but also because their brain cells may process those inputs differently.

This became more widely appreciated in 2015 when social media exploded with arguments about “the dress”: an image of a two-tone garment that some saw as white and gold and others said was blue and black. “It’s hard to understand that other people might see the world differently, [until] you get weird things like the dress,” says Anil Seth, a neuroscientist at the University of Sussex, UK.

Seth and his colleagues are investigating the diversity of human sensory experiences through the Perception Census, an online survey of how people experience games, illusions and other visual and auditory stimuli. “There are differences that we know about and are nameable – people that are colour blind, for example,” says Seth. “But we want to understand differences that are in the middle of the distribution rather than the tails.”

If it is hard to really know the minds of other people, then it is arguably even harder to get a window into those of other species with completely different sensory inputs (see “What is it like to be a bat?”, page 44). Or how about the experiences of an intelligent machine, with a “mind” that isn’t even made of the same basic materials as us – surely that would be harder still to comprehend?

This leads to a serious problem: how will we know if we ever create an AI that is sentient? It may be that we will have to judge a computer’s consciousness not by counting how many processors it has, but simply by whether it gives the appearance of sentience. This may seem rather unscientific, but it is the same method used for judging the sentience of our fellow humans. After all, we cannot know for sure if other people have consciousness like our own, we merely assume it, based on their behaviour.

No matter how well we may be able to understand reality through science, using equations, theories and experimental measurement, there is always going to be a crucial aspect that remains at least partly private and unknowable. “There’s this direct experiential knowledge, which only the organism with a particular brain can have,” says Seth. **Clare Wilson**

WILL WE EVER SOLVE THE LIAR PARADOX?

What are we to make of the sentence “This sentence is false”? If we say the sentence is true, then it is false. If we say it is false, then it is true. Whichever we choose, there is a violation of a common-sense rule: declarative sentences ought to be either true or false, not both. This kind of paradox rarely crops up in everyday life, of course, and some have suggested that we can avoid problems by having better linguistic rules that exclude paradoxes.

But there are other ways to respond to this puzzle, says Margaret Cuonzo, a philosopher at Long Island University in New York. “One is to say that our logic needs to be revised to handle more complex phenomena.” This is the route a few philosophers have taken. For instance, an approach called dialetheism says that some things can be true and false at the same time. But this gets complicated. Proponents of dialetheism have to figure out “how claiming something can be true and false doesn’t lead to a system in which you can prove anything”, says Cuonzo. If things can be true and false, facts start to lose meaning. This is one paradox that remains deeply challenging to explain away.

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WHAT IS IT LIKE TO BE A BAT?

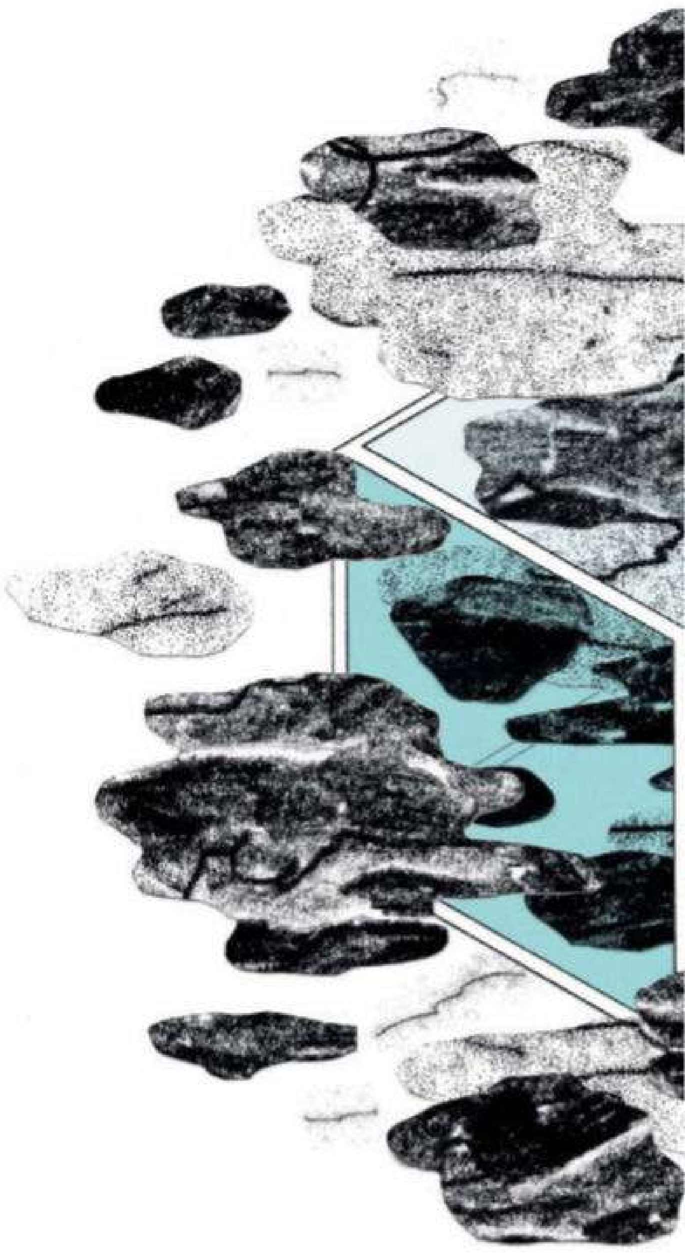
Philosopher Thomas Nagel considered this question in the 1970s in order to argue that it isn't possible to understand the conscious experience based on our physical understanding of the world alone. Whatever your view on that issue, it hasn't stopped people trying to understand things from animals' point of view. One far out example is the designer Thomas Thwaites, who, in 2016, tried to live as a goat on a hillside. He built a goat exoskeleton and external stomach to help him digest grass – no kidding.

Ultimately, Thwaites and others have found there is a wide gulf between our experience of the world and that of some animals. How are we ever going to grasp what it is like to "see" the world through the lens of echolocation? "You can chop up a bat, you can find out everything about its physical construction down to the last atom, but its private, phenomenal feel is going to elude you," says Stephen Law, a philosopher at the University of Oxford.

This makes it hard to form judgements about the ethical treatment of animals. And the more different the species is from us, the harder this becomes, says Anil Seth at the University of Sussex, UK. "We might be able to imagine what it's like to be a monkey more than what it is like to be an octopus. But we probably still get it wrong for a monkey."

Bats experience the world differently

BARRY MANSELL/NATUREPL



Limit 5

When logic itself might be fatally flawed

I AM not bald. At least, not as I write this. Yet if a malevolent philosopher were to pluck the hairs out of my head, one by one, I would end up bald. But how many would have to be removed before I went from having a lustrous head of hair to being bald? It is tricky, if not impossible, to say. And if we can't identify the transition to baldness, am I actually bald at all?

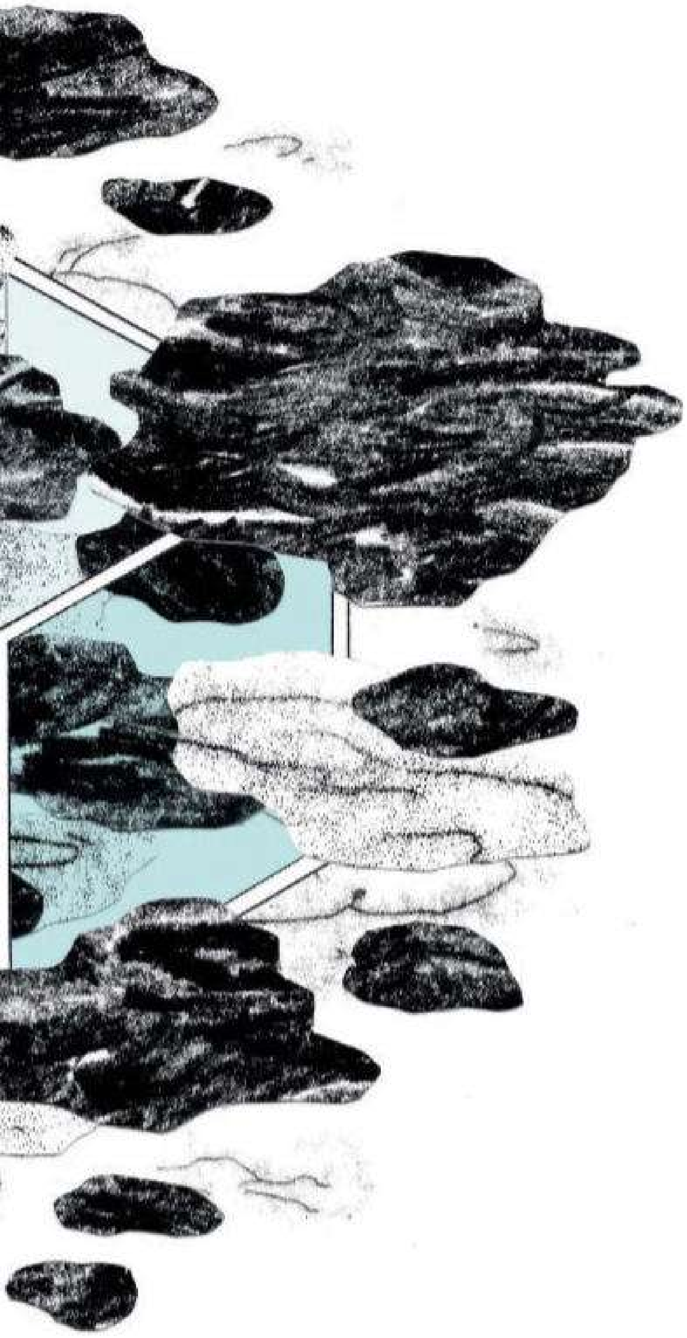
This is a version of a thought experiment favoured by philosophers, first described with reference to grains of sand in a heap, called the sorites paradox (from the Greek word for "heap"). It is often used as evidence that classical logic might be insufficient to describe the world around us.

That is troubling because, though we don't pay it much attention, logic runs through human knowledge as if it were a stick of rock. We assume that we can build up a sequence of facts into systems of thought. But if logic itself is lacking, where does that leave us?

Paradoxes start with a premise that seems true, apply reasoning that also seems valid, but end up at a false or contradictory conclusion. As a result, many paradoxes force us to question what we think we know. They come in different varieties, some more difficult to explain away than others. One of the most confounding takes the form of a simple sentence (see "Will we ever solve the liar paradox?", page 43).

One solution to the sorites paradox is to admit that terms are sometimes too vague to be useful outside of everyday conversation. But some philosophers argue that logic itself needs a refresh. One approach is to say that there are different degrees of truth. Take the case of my hair removal. Halfway through the process of plucking, I am still not bald, but I am less

> "It is likely that there is a higher mode of logic that human minds wouldn't be able to grasp"

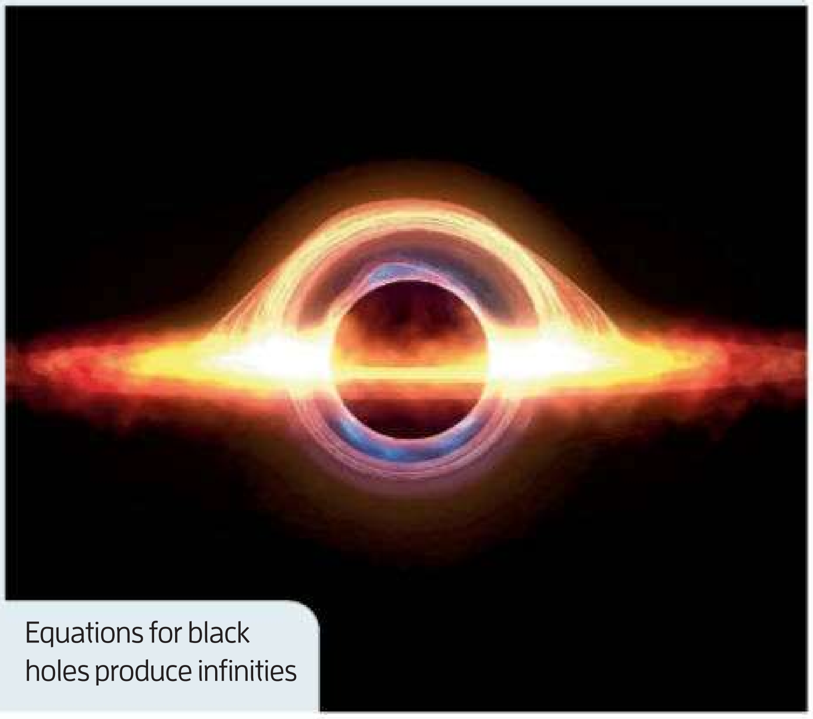


HOW BIG IS INFINITY?

Infinity is infinitely big, right? Sadly, it isn't that simple. We have long known that there are different sizes of infinity. In the 19th century, mathematician Georg Cantor showed that there are two types of infinity. The "natural numbers" (1, 2, 3 and so on forever) are a countable infinity. But between each natural number, there is a continuum of "real numbers" (such as 1.234567... with digits that go on forever). Real number infinities turn out not to be countable. And so, overall, Cantor concluded that there are two types of infinity, each of a different size.

In the everyday world, we never encounter anything infinite. We have to content ourselves with saying that the infinite "goes on forever" without truly grasping conceptually what that means. This matters, of course, because infinities crop up all the time in physics equations, most notably in those that describe the big bang and black holes. You might have expected mathematicians to have a better grasp of this concept, then – but it remains tricky.

This is especially true when you consider that Cantor suggested there might be another size of infinity nestled between the two he identified, an idea known as the continuum hypothesis. Traditionally, mathematicians thought that it would be impossible to decide whether this was true, but work on the foundations of mathematics has recently shown that there may be hope of finding out either way after all.



Equations for black holes produce infinities

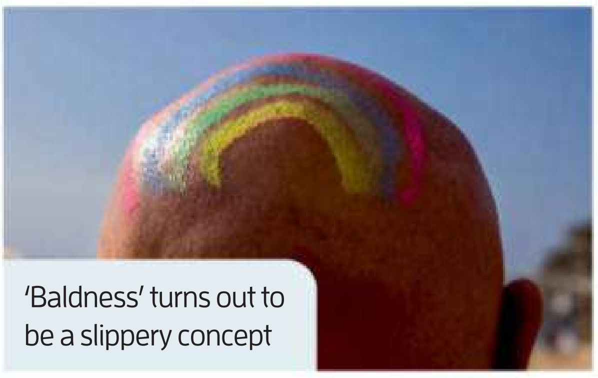
O_M/SHUTTERSTOCK

"not bald" than I was at the start. Fuzzy logic, a kind of computing using degrees of truth rather than 1s and 0s, was introduced by computer scientist Lotfi Zadeh in 1965. It is still used in some artificial intelligence systems today, like IBM's Watson.

Another approach, called supervaluationism, provides a way to discuss vague concepts by categorising some statements as "true" and others as "supertrue". Imagine a minor character in a story, for example. If we aren't told how many siblings they have, we can say that it isn't supertrue that they have three siblings. It is true, however, as long as there is no information in the story to tell us otherwise. "The bold claim is that truth – ordinary truth – really is supertruth, and falsity is superfalsity," says philosopher Brian Weatherson at the University of Michigan.

But there is a deeper question here: can we be sure that logic, even a reformed kind, is enough to understand the universe in all its fullness?

It is a question that David Wolpert at the Santa Fe Institute in New Mexico has been thinking about for decades. In a recent monograph, he spelled out his argument that it is more likely than not that there is some higher mode of logic that could be used to understand the universe, but that human minds wouldn't be able to grasp.



'Baldness' turns out to be a slippery concept

JENNY EVANS/GETTY IMAGES

Just think of that humble linguistic device, the question. Wolpert says there are creatures – things like a single-celled paramecium – that couldn't conceive of the idea of a question. In fact, according to our standards of intelligence, every other species on Earth is limited in some regard in the way it understands the world around it. Why should we be any different? "We are the paramecia," says Wolpert. "What is beyond us?"

Wolpert thinks there are ways we could potentially get at higher systems of thought that go beyond logic as we know it. Perhaps it will be a super Turing machine that can transcend the normal rules of computing or an intelligent form of extraterrestrial life that shares its wisdom with us. Perhaps it will be something different altogether. And what will this new plane of understanding be like? "I can't conceive of it," says Wolpert. "But that's the whole point." ▮ **Abigail Beall**

How to be happy

Robert Waldinger leads the world's longest-running study of happiness. He tells Alison Flood what he has learned about the secrets to a contented life

WHEN talking with Robert Waldinger, it is difficult to ignore the fact that he seems extremely content. A side effect of his job, perhaps. As the director of the longest scientific study of happiness ever conducted, it would be rather disappointing if he was anything else.

The Harvard Study of Adult Development (HSAD) began in 1938, with 724 participants: 268 undergraduate students at Harvard College and 456 14-year-old boys who had grown up in some of the most disadvantaged neighbourhoods in Boston, Massachusetts.

All were interviewed and given medical exams on joining the study. Throughout their lives, participants had regular brain scans and blood tests and took part in further interviews, as researchers set out to find answers to what makes a happy and meaningful life.

More than eight decades later, HSAD has expanded to include three generations and more than 1300 direct descendants of the original participants. Waldinger, who is also a professor of psychiatry at Harvard Medical School and director of the Center for Psychodynamic Therapy and Research at Massachusetts General Hospital, has co-written *The Good Life* with the study's associate director, Marc Schulz, bringing together case studies with the latest psychological research to share what they have learned about how to live a happy life.

Alison Flood: How do you define happiness?
Robert Waldinger: There are two big bins that happiness seems to fall into. One is hedonic happiness. It's like, am I having fun now? It's a moment-to-moment, fluctuating experience. Then there's eudaimonic happiness, which is a sense of life having meaning and being worthwhile. For example, you're reading to your child before bed. You've read the same book eight times, but she wants you to read it again. You're exhausted. Is this fun? No. But is this the most meaningful thing you could imagine doing? Yes. In our studies, we think about well-being a lot, which is more eudaimonic happiness than moment-to-moment happiness.

How do you track happiness throughout a person's life?
We have questionnaires that literally ask questions like "how happy are you?". But that's not the whole story. Someone could tell you "yes, I'm happy" because they think they're supposed to, but they may not be. So we also measure well-being by, for example, asking: "Who could you call in the middle of the night if you were sick or scared?" Those aren't direct questions about whether you are happy, but about how connected you are and how secure you feel in those connections.

We also do medical tests – measuring stress hormones, for instance. We do a whole variety of things to try to use as many different lenses as we can to look at well-being. We only present findings that other studies have corroborated. In this kind of work, where you're studying human beings, and it's so messy and complicated, no single study can prove anything. And so what you want is multiple studies that point in the same direction.

With more than eight decades of data at hand, what is the most important thing you have learned?
The big, surprising takeaway is how much having warm connections with other people predicts how long you stay healthy, how long your brain will stay sharp. Having these good connections makes you less likely to get coronary artery disease. You're even less likely to get arthritis.

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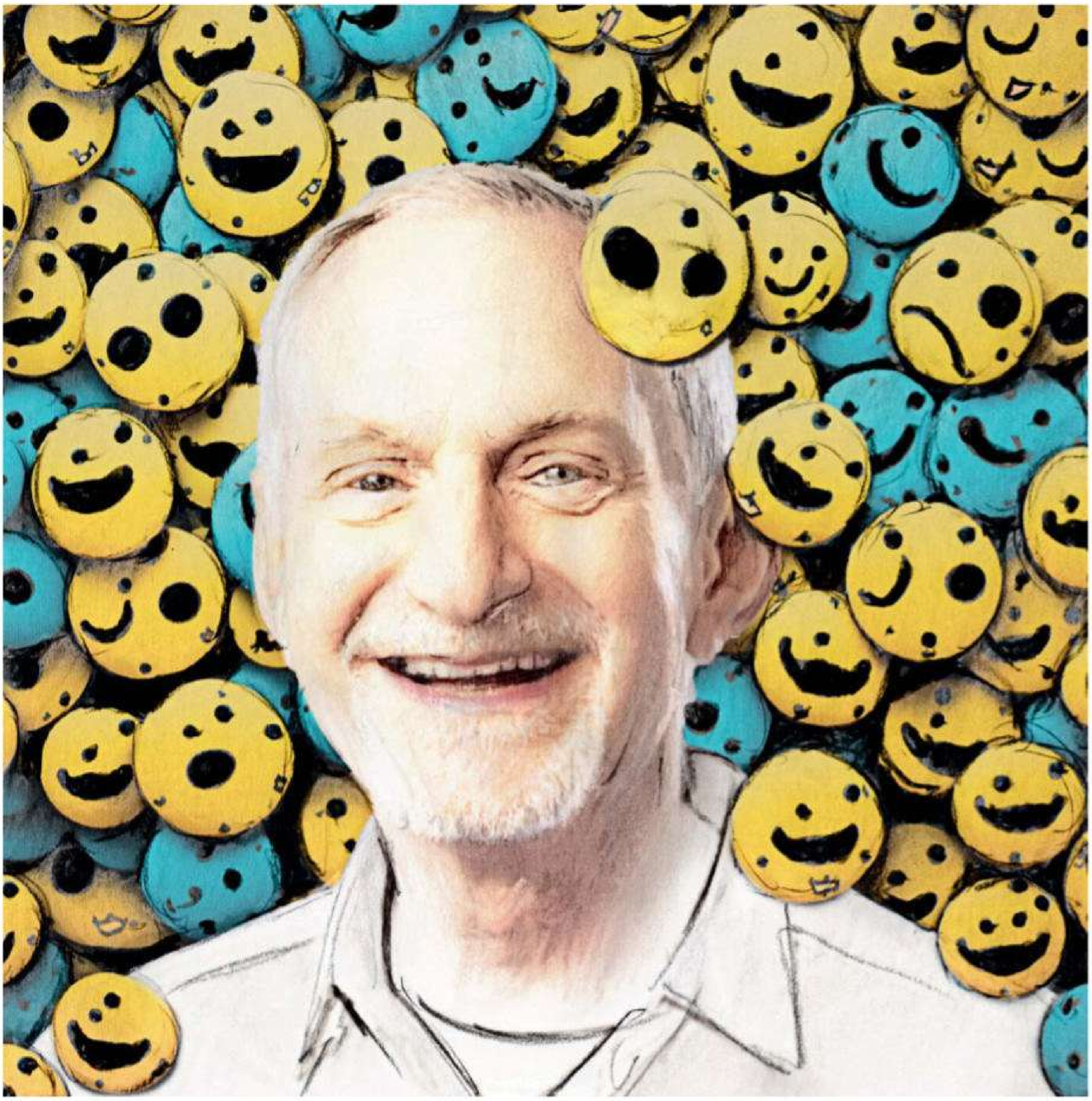


NIBALI NEZZAR

Can you explain what you mean by "warm"?
Warm equals a relationship that feels supportive. That could mean emotional support, advice, financial support, logistical support. Anything that could be called supportive, as opposed to relationships that feel draining, acrimonious or exploitative.

Which relationships are best for us?
There are different kinds of relationships that confer health benefits. One type is what we call a secure attachment relationship: that person who you could call in the night if you were sick or scared. Everybody needs somebody like that in their life. Other types of relationships that convey health benefits are friendships, family relationships, work relationships. And some of them, we're learning now, are what are called "casual ties": the person who makes your coffee for you at the coffee shop every day, who you exchange some pleasant words with; the person who checks out your groceries in the grocery store, who you see every week. Those more casual ties turn out to give us little hits of well-being as well.

More than 200 papers have been produced from HSAD's data. Can you tell me more about what has been discovered?
Yes, we have studies showing that warm connections actually reach across our whole lives to affect our well-being. One study from 2016 used data collected on 81 males from adolescence through to the eighth and ninth decades of life and shows that the warmth of your connections to your parents in childhood predicts how securely attached you are to your intimate partner 60 years later. It is pretty remarkable to see a connection across this much time because so much else happens to us. It speaks to the strength of the effect of early warmth on later well-being. A 2015 study of 81 elderly heterosexual couples showed that more secure connections with partners in late life actually predicts greater brain health and well-being several years later. And a study from 2010 of 47 older adult couples over an eight-day period showed that warm connections with partners buffer us from mood dips when we're in pain.

Is it important to have a life partner?
We found that you don't need to have a life partner or an intimate partner to get these benefits. Many different kinds of relationships provide us with them. A sizable percentage of people don't have life partners or intimate partners. That does not mean you're doomed to a life of unhappiness or poor health. You can find those good connections in other places.

> "The warmth of your connections to your parents in childhood predicts how securely attached you are to your intimate partner 60 years later"

Romantic partners aren't necessary to build happiness

JOZEF POLC/ALAMY

MOMO PRODUCTIONS/GETTY IMAGES

Is there someone you would describe as the study's happiest participant?
Leo. He was a man who went to Harvard and dreamed of being a writer, a journalist. But his life circumstances were such that he needed to go home after serving in the second world war and take care of an ailing parent. He got a job as a history teacher at a local school and he loved teaching. He had three daughters and he loved them. He had a good marriage. He built a life of warm, engaged relationships. It wasn't a life where there was a huge amount of achievement, but he was very happy. He was an example of how being invested in your connections with other people is a constant source of nourishment and energy.

What about the study's most unhappy person? There is a really moving part of your book where you talk about a man who was so isolated that, when your researcher got into the car with him, dust fell off the seatbelt because he hadn't had a passenger for so long.
This was a man who was very isolated, but didn't realise how isolated he was. He kept telling himself things were OK, but he was so alone. He had deep, nagging fears about connecting with people – a fear that he'd be a bother to his kids, that people wouldn't

Reading to children boosts your sense of worth and well-being

want to be with him. He would make one decision after another that kept him away from people. We found that the people in our study who kept prioritising connections, and kept making those small decisions to connect day after day, were the people who stay happier and healthier.

Do you think that the things that make people happy have changed over the decades, or are the fundamentals consistent?
I think the fundamentals are biologically ingrained. We evolved to be social animals. That's a very important evolutionary concept. As we evolved as a species, the people who were more social were more likely to survive and reproduce and, because of that, more likely to pass on their genes. And that's why I think it doesn't change that, generation after generation, we continue to need social contact.

Is there such a thing as a baseline level of happiness set by our genetics?
We believe there is. You're pointing to something we think of as inborn temperament. You probably know people who are generally gloomy, and then you know people who are cheery and, almost no matter what, upbeat. We believe that this is somewhat biologically based, probably genetically determined. A psychologist named Sonja Lyubomirsky estimates that about 50 per cent of our individual levels of happiness are genetically determined. About 10 per cent, she estimates, is due to life circumstances. The remaining 40 per cent of our happiness can be changed, and that means that 40 per cent is in our control. That's a big chunk. So that's why we spend time studying happiness and figuring out what can we do to make ourselves happier. Because we can move the needle.

When these studies started out, they were looking at white men. Are the findings of your study relevant to those outside this demographic?
Most definitely. More than half of our participants now are women. Our study includes very poor, disadvantaged people and very privileged people. About 40 per cent of our original participants were from immigrant families. Our findings are also corroborated by other studies. When many different studies of many diverse groups of people find the same thing, we have confidence that what we're presenting is true and is relevant to people of many different demographics.

Do you think being part of the study made a difference to the lives of those who participated?
We asked them. Some people wrote back saying it didn't affect them. Some said "your questions were a nuisance". Many said "I knew that every year or so, I would be asked to check in on my life. And I would ask myself these questions about where's my life going". They said "this was a really important part of my life, and it undoubtedly changed the way I think about life". Of course, that means we weren't a hands-off study. We affected the people we were trying to observe. But it's impossible to do this kind of study without that happening to some extent.

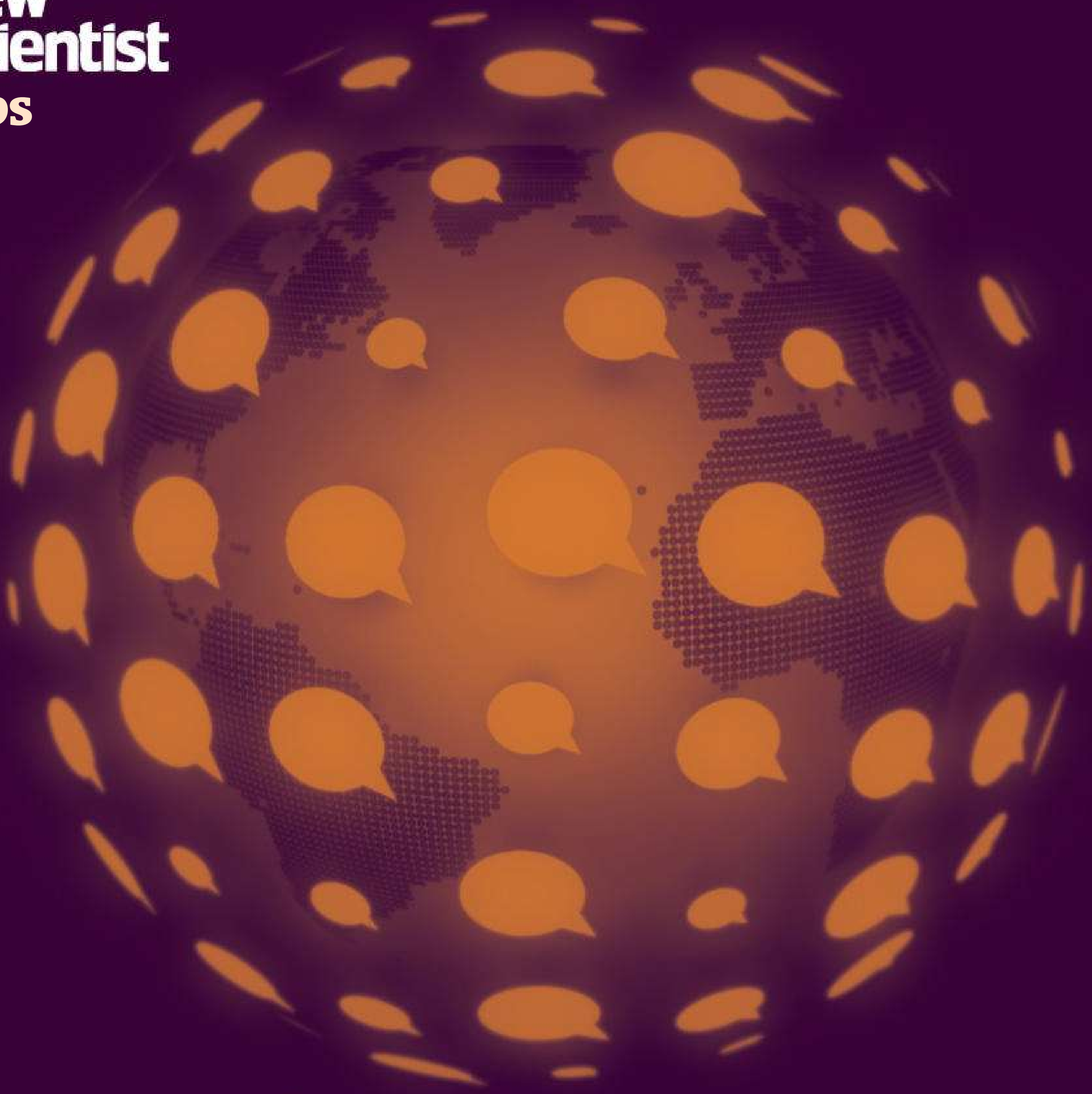
In your book, you talk about "social fitness" – how important is it to pay attention to this and how do we improve it?
We came up with social fitness as something similar to physical fitness. If you go to the gym, you don't come home and say: "I've done that. I never have to exercise again." But a lot of us think that our good friends are always going to be our friends and that we don't have to do anything to take care of those friendships. In fact, perfectly good relationships can simply wither away from neglect. So we talk about the idea that it really is important to reach out to friends and family to keep maintaining those valuable connections.

Small actions can make a difference. Sometimes, when I give a talk about this, I'll say: "OK, I want you to think about one person who you miss. Now, I want everybody to take out their phone and text that person right now. And just say 'hi, I was thinking of you and wanted to say hello'." When people do this, they report things like "my friend was so glad I reached out". The point is that these tiny actions can start to have ripple effects.

Finally, what about moment-to-moment, hedonic happiness. How do we get more of that?
Ultimately, if you build strong relationships and work on maintaining these, you'll make it more likely you'll have moment-to-moment happiness by building this bedrock sense that life is good. ▮

Alison Flood is *New Scientist*'s comment and culture editor

New Scientist
Jobs



In association with srg

2023

Global Salary Survey (STEM)

New Scientist Jobs, in association with SRG, is conducting its Global Salary Survey 2023 (STEM) to provide you with the latest insights.

If you work in STEM, we would love your thoughts and feedback. To find out more and complete the survey, go to

newscientist.com/salarysurvey

Puzzles
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***Almost* the last word**
Could photons that were near me decades ago still exist? p54

Tom Gauld for *New Scientist*
A cartoonist's take on the world p55

Feedback
A unique chance to compare a man with a pea p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

Science of gardening

Talking rhubarb

Depriving rhubarb plants of light for several weeks forces them to grow fast and gives an earlier harvest, says **Clare Wilson**

Clare Wilson is a staff writer at *New Scientist* and writes about everything life-science related. Her favourite place is her allotment @ClareWilsonMed

What you need

Rhubarb crowns for planting
An old dustbin or terracotta forcing pot
Duct tape (optional)
A large brick
Fish blood and bonemeal or well-rotted horse manure

I HAVE just finished one of the few winter jobs at my allotment: preparing my rhubarb patch, including setting up one of the plants to be forced. This means covering it with a large container to make the stalks grow more quickly in search of light.

If you have the space, I highly recommend getting a few rhubarb plants as they are so easy to grow. I give mine little attention, but each spring they produce a huge crop when there isn't much home-grown produce around. Technically, rhubarb stems are a vegetable as they are the plant's leaf stalks, but they need plenty of added sugar to combat their acidity, which is due to a compound called oxalic acid. So, when it comes to cooking, they are used as a fruit.

Forced rhubarb is sweeter than the ordinary kind as it has less oxalic acid. The forced stems are also pinker because plants can't make the green pigment chlorophyll in the absence of sunlight, which makes for nicer-looking desserts. But the chief advantage of forcing rhubarb is that the stems can be harvested sooner, as early as February in the UK, while those left unforced can take a month or two longer.

It is possible to buy elegant, terracotta forcing pots to exclude the light, but, for economy, I use an old, black rubbish bin with duct tape over any holes or cracks and a large brick placed on top to weigh it down. To speed up growth, you can also insulate the rhubarb plant by covering it with straw or by wrapping some old carpet around the outside of the bin.

GAP PHOTOS/CLIVE NICHOLS

Now would be a good time of year in the northern hemisphere to plant some rhubarb crowns, so long as the ground isn't frozen. Ten years ago, I planted five in a row and pegged down a metre-wide roll of weed-suppressing membrane over them, with crosses cut into it so the top of each plant could poke through.

Every winter, when the plants' leaves and stems have died off, I feed them with rotted horse manure or a helping of fish blood and bonemeal. Then, I simply plop my dustbin over the top of one of them. The forcing process weakens the plant, so don't do it to the same one for two years running, and only begin once the plants are well established.

When the time comes to harvest your rhubarb, rather than cutting or snapping the stems, just pull them off by gently twisting from the base. This encourages the plant to put up more shoots in the future. Don't eat the leaves, as they have such high oxalic acid levels they are poisonous.

By boiling or baking the stems with sugar to taste, you can turn them into a crumble, fool, pie, tart or compote. Or make rhubarb and custard ice cream, which you can do by layering dollops of the two components in a plastic tub and putting it in the freezer for 2 hours. Serve semi-frozen, ideally with thin ginger biscuits. ▮

Science of gardening appears every four weeks. Share your gardening successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistGardening

Next week

Citizen science

These articles are posted each week at **newscientist.com/maker**

Swansea University
Prifysgol Abertawe

Computational Foundry
Ffowndri **Gyfrifiadol**

EPSRC Centre for Doctoral Training in Enhancing Human Interactions and Collaborations with Data and Intelligence Driven Systems – Call for Applications for 4-year Funded research studentships.

"Permacrisis" is the Collin's Dictionary word of 2022, reflecting the very real global concerns we have all experienced. It is easy to despair but at Swansea University we are working to use AI and data-driven systems to bring hope and transformation. We do this by focussing on the most important technology of all: people. We are now looking for the next group of PhD researchers to join our Centre, people who are committed to changing the world via world-class research that focuses on amplifying human capabilities using data driven and intelligence enabled systems. The programme spans 4-years and includes an integrated Masters.

Working alongside a rich and diverse set of partners – including Facebook, Siemens, Tata, NHS and Google – successful candidates will use a people-first approach to drive exciting, adventurous and impactful socio-technical breakthroughs.

The Centre is housed in the state-of-the art Computational Foundry at Swansea University. Members of the Centre will be nurtured by multi-disciplinary supervisors with globally leading research agendas in Computer Science, Mathematics, Engineering, Management, Medicine and Social Care and Law. If successful, you'll be part of a community of 40+ PhD researchers, each supporting and learning from each other.

Candidates should have an aptitude and ability in computational thinking and methods including the ability to write software or enthusiasm to learn how to do so. While such aptitude might be evidenced by a degree in Computer Science or Engineering, we are building a community that aspires to have a high degree of diversity of perspective. So, if you have a background in Arts and Humanities; Social Sciences; Management for instance, please be encouraged to apply.

For future AI and big data technologies to serve society and the economy effectively, they must be created and critiqued by a diverse and wide set of perspectives as possible: we welcome applications from anyone who feels they can help in the Centre's mission.

This year, we have 12 fully funded places (fees plus stipend set at the UKRI rate).
Places are also available for those in receipt of four-year external funding.
We welcome candidates from anywhere in the world.

To discuss your application, please contact Professor Matt Jones (Director-Enhance-CDT@swansea.ac.uk)

Royal Academy
of Engineering

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Chair in Emerging Technologies – Now Open

Funded by the UK Department for Business, Energy and Industrial Strategy, the Royal Academy of Engineering invites global research visionaries to apply for this highly prestigious award. We will provide long-term support for high calibre researchers to lead on the development of an emerging technology, facilitate its commercialisation, and create significant UK economic and social benefit.

£2.5M award value over ten years. Awards must be held at a UK university.

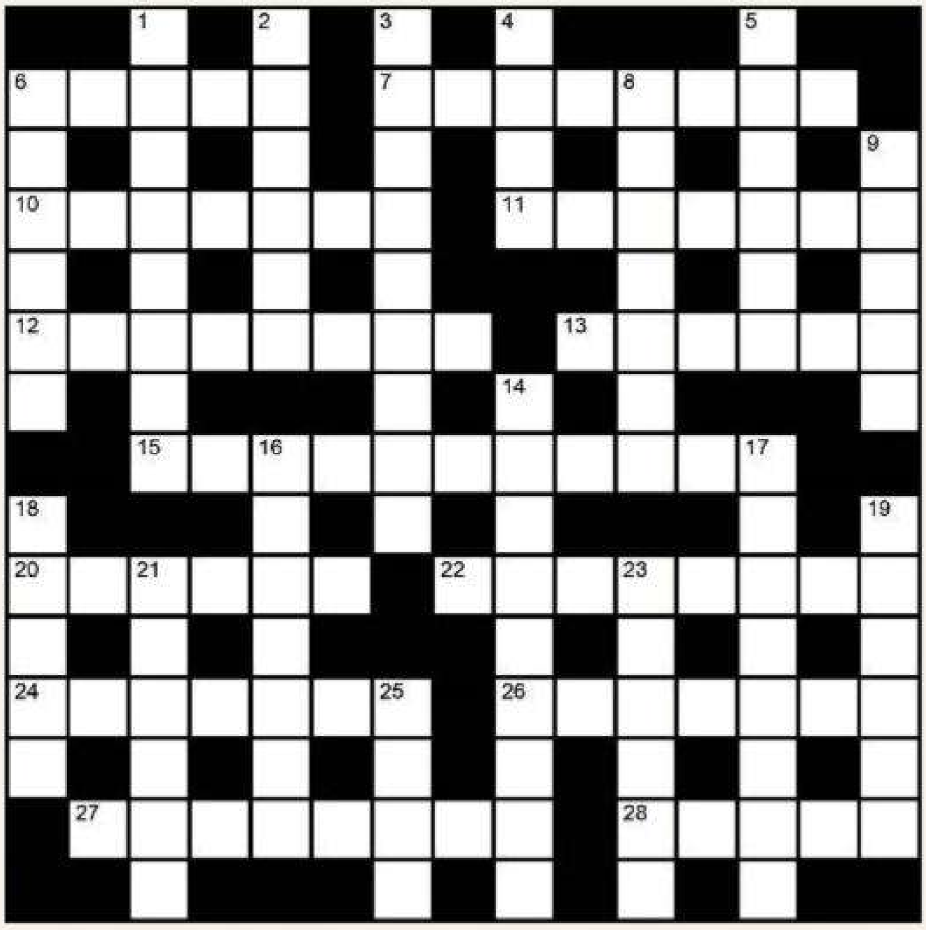
We also welcome applications from high-calibre researchers currently based outside the UK.

Apply by 16.00 GMT, 11 April 2023.

Applications welcome across all engineering disciplines, and we encourage applications from women and all other underrepresented groups in engineering.

For more information and to apply, please visit www.raeng.org.uk/ciet or contact research@raeng.org.uk

Quick crossword #124 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

6 Procedures undertaken prior to surgery (3-2)
7 Device for examining the ear (8)
10 Model construction system launched in 1898 (7)
11 Lock opening (7)
12 Type of curve, in mathematics (8)
13 C_2H_2 (6)
15 Migratory wetland songbird (4,7)
20 Drilling platform (3,3)
22 Not acid or pH-neutral (8)
24 Wading bird also called a courlan, found in the Americas (7)
26 Large, dense body of ice (7)
27 Inhabitants of the Red Planet, possibly (8)
28 Relating to the lowest part of the small intestine (5)

DOWN

1 Gerardus ___, 16th-century map-maker (8)
2 Ligament damage (6)
3/18 Long-running BBC science series (9,5)
4 The yellow of an egg (4)
5 "___ action at a distance", Einstein's term for quantum entanglement (6)
6 Low-density volcanic rock (6)
8 Material formed of molecules in an ordered lattice (7)
9 Fourth prime number (5)
14 Genitourinary specialist (9)
16 Online token or pass (1-6)
17 Nasal inflammation (8)
18 See 3
19 ___ system, collection of measurements based on the metre (6)
21 Relating to the abdominal region (6)
23 Tree also known as a wattle (6)
25 Of a tide, minimal (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #184
set by Bethan Ackerley

1 In physics, who coined the term "quark"?

2 A tiny chamber produced by a plant that houses arthropods is known as what?

3 Arcturus is the brightest star in which constellation?

4 How many types of influenza virus are there?

5 The site of the ancient city of Assur is in which modern-day nation?

Answers on page 55

Puzzle
set by Peter Rowlett
#204 Think of a number

My son's book of mathematical magic tricks includes this one:

1. Think of a whole number from 1 to 50.
2. Add 9 and double the result.
3. Multiply by 6 and add 12.
4. Subtract 60.
5. Divide by 12 and subtract 4.
6. Subtract your original number.
7. And the answer is (drumroll...) 1!

Unfortunately, when he is reading, my son sometimes repeats a line and sometimes he skips one. That happened with this trick. He did one of the lines twice and then missed the final instruction to subtract his original number. Yet, by an incredible fluke, he still managed to end up on the number 1.

What number did my son think of?

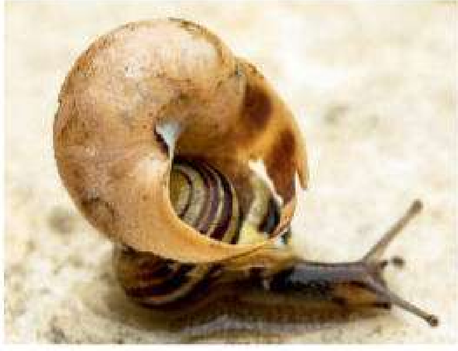
Solution next week

Snail double

I found a snail (pictured below) in my garden carrying an extra shell on its back. How common is this and what is its purpose?

Gerald Legg
Hurstpierpoint, West Sussex, UK
The snail with the extra shell belongs to the genus *Cepaea*, either a white or brown-lipped snail. It is carrying the broken shell of a garden snail, *Cornu aspersum*. The damage to the latter looks like it was sustained by a thrush breaking it. The *Cepaea* must have accidentally picked up the broken shell while moving around.

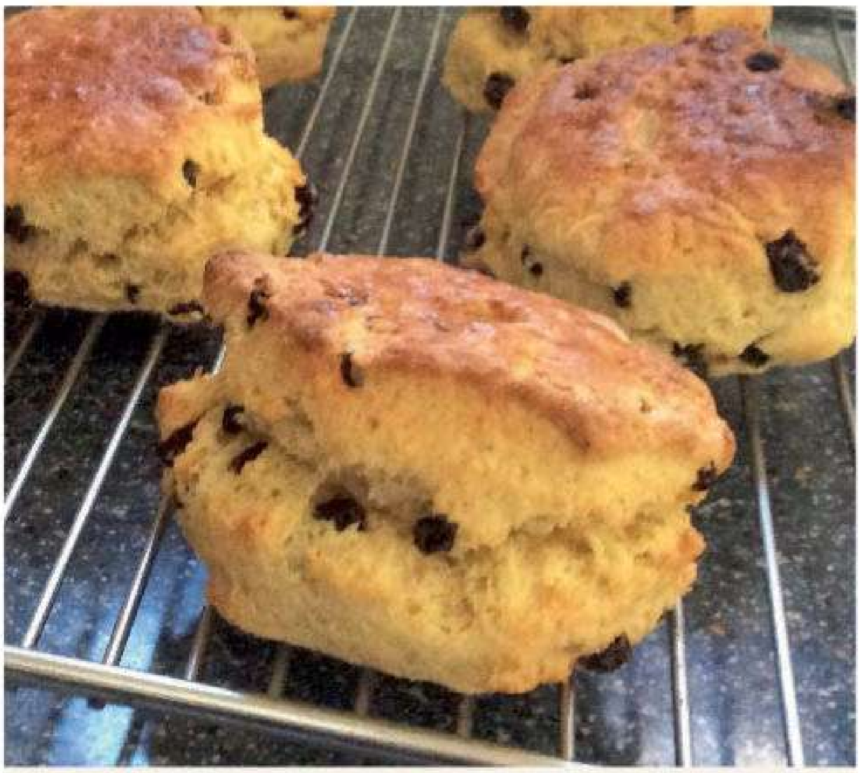
I haven't seen a snail carrying an object on its shell before, but underwater I have seen sea urchins carry pieces of shell on their backs, which are apparently useful sunshades.


JOHN DAVIES

Stray photons

Could any of the photons that were around me when I played outside as a child decades ago still exist, travelling through space?

Eric Kvaalen
Les Essarts-le-Roi, France
Yes. In fact, about half the photons that were reflected off you when you were outdoors went upwards. If they didn't hit a cloud, most of those would have gone right through the atmosphere into outer space. Almost all of those still exist. A very small percentage hit the moon or the sun and came to an end. Far fewer hit planets or other solar system bodies. An even smaller number hit Alpha Centauri or other nearby stars. The vast majority are still flying, dozens of light years away.


GEOFF ROWLANDS

How do scones form a natural "waist" as they rise in the oven?

This week's new questions

Shapely bake How does a scone develop a "waist" as it rises in the oven? ***Geoff Rowlands****, Falmouth, Cornwall, UK*

Feeling light On the night side of Earth, the sun's gravitational pull on me will be additive to that of Earth, whereas on the light side it will be subtractive. So, do I weigh more at night? ***Andrew Doble****, Hamilton, Bermuda*

Guy Cox
Sydney, Australia
Photons are easily absorbed, but they don't decay. Our giant telescopes capture photons that are billions of years old. But those from your childhood will be a long way away. Any surviving photons that were around me as a schoolboy are now at least 60 light years away.

Mike Follows
Sutton Coldfield, West Midlands, UK
What an enchanting idea. Yes, many of the photons that flashed past you as a child will still be hurtling across the galaxy and they will keep going until they are absorbed – perhaps in the eye of a yet-to-be-born life form. After all, the photons that comprise the cosmic microwave background set off on their journey roughly 14 billion years ago, about 400,000 years after the big bang.

Things get complicated when thinking about the photons before they were reflected by the scene around you, because it isn't clear that reflected photons are the same entities as incident ones. Indeed, perhaps the same could be said of any skyward photons that ricocheted off particles on their journey out of our atmosphere and beyond.

Of course, you won't have seen any of those photons that are now light decades away. Your visual memories were created by some of the photons that didn't escape to space, but ended up triggering interactions in the photoreceptors at the back of your eyes.

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Chris Daniel
Colwyn Bay, Conwy, UK
The potential lifetime of a photon is thought to exceed the age of the universe. However, whether the exact same photons that were around us decades ago still exist is a difficult question to answer.

A photon is a package, or quantum, of electromagnetic energy, and when one hits an object, its energy is converted into the internal energy of that object. This energy may be absorbed as heat, meaning that the photon no longer exists, or it may be momentarily contained by an excited electron, which then releases it as a new photon of transmitted, reflected or scattered light, depending on the material.

But is it the same photon? Although a reflected photon may not be continuous with the original one, it is identical to it, the quantum information having been preserved with the same energy, wavelength and frequency.

Photons may, therefore, have multiple existences, but they carry the same quantum information as they bounce, scatter and illuminate the world around us. With luck, some from our childhood will have made their way out through the atmosphere into space, where they will keep going until they meet other distant objects that they might be re-emitted from or in which they might finally be absorbed and cease to exist.

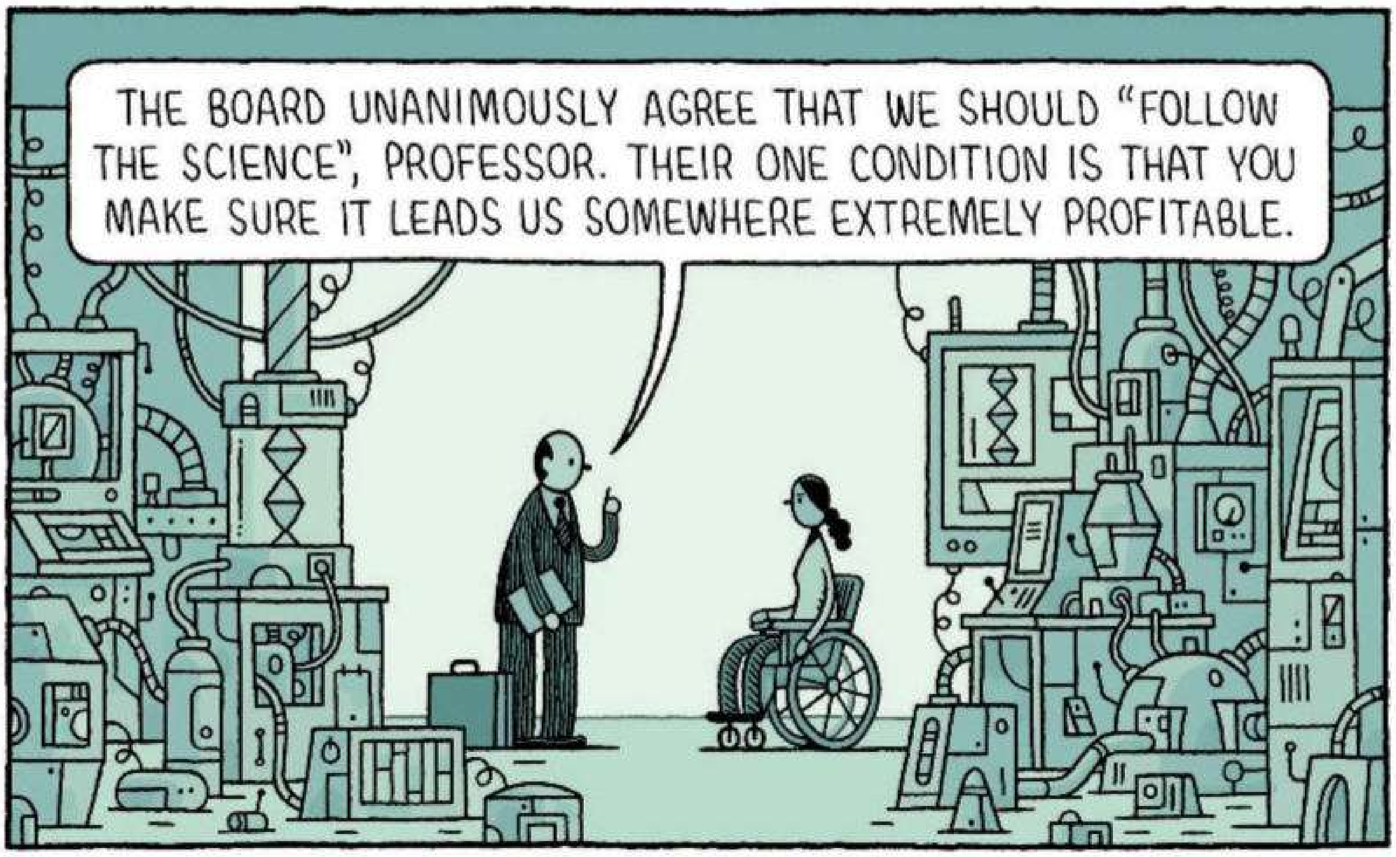
Red alert

Why are many people squeamish about the sight of blood when, for much of history, we had to butcher animals? (continued)

Andrew Charters
Holmfirth, West Yorkshire, UK
Your correspondence about squeamishness and blood (26 November 2022) made me think of my early experiences as a medical student. From the first

Tom Gauld

for New Scientist


THE BOARD UNANIMOUSLY AGREE THAT WE SHOULD "FOLLOW THE SCIENCE", PROFESSOR. THEIR ONE CONDITION IS THAT YOU MAKE SURE IT LEADS US SOMEWHERE EXTREMELY PROFITABLE.

week, we had to dissect dead bodies. Ours were decapitated because the dental students needed the heads. We also had the opportunity of watching open heart surgery. In both cases, group bravado helped to overcome squeamishness.

A bit later, we observed operations from within the operating theatre. The fact that you had nothing useful to do and were the least experienced in the room, with all of its sounds and smells, made some of the students squeamish. Later still, we assisted at operations, which mostly involved using all of our strength to "retract" the liver, pulling it out of the way for the surgeon.

Having something useful to do and being part of a team removed any squeamishness. So I would suggest that being active rather than passive is another important dimension to this question.

Julian Money-Kyrle
Calne, Wiltshire, UK

After 30 years of medical practice, it seems to me that people are more squeamish about their own blood than other people's.

> **"Some of the photons that were around us in childhood will have made their way out of the atmosphere and into space"**

Those who are squeamish react with a sharp drop in blood pressure, which may be accompanied by fainting. I would hypothesise that this is a survival reflex, with the drop in blood pressure reducing bleeding for long enough for the various clotting mechanisms to kick in.

I have also noticed that I often feel a bit squeamish when I see blood or injuries on television, particularly in dramas where the aim is to maximise the emotional impact in relation to the plot. However, the same sights don't bother me in real life. I think this is because, in reality, I am usually trying to do something to help, which requires an analytic rather than an emotional response.

Hot and frothy

Please help settle a friendly argument about coffee. Does a latte cool faster than a cappuccino, all else being equal (initial temperature, volume, etc.)? My friend thinks the foam on a cappuccino will insulate it better, but I reckon this effect is offset by the cappuccino having a smaller volume of hot milk. (continued)

Paul Whiteley
Bittaford, Devon, UK

This is an ideal question to demonstrate why empiricism beats theoretical musing. The way this query was answered previously (10 December 2022) was in terms of heat absorption, evaporative cooling, conduction coefficients, latent heat etc. (though the answer missed out colour: darker colours radiate heat quicker). All of these parameters require a considerable amount of data and prior research to establish coefficients.

The empirical answer is to stick a thermometer into each cup and measure them. ▮

Answers

Quick quiz #184
Answers

1 Murray Gell-Mann
2 A domatium
3 Boötes
4 Four: A, B, C and D
5 Iraq

Cryptic crossword #100 *Answers*

ACROSS 1 Aura, **3** Triassic, **9** Engross, **10** Tacit, **11** Halley's comet, **13** Sierra, **15** Cohere, **17** Foraminifera, **20** Ochre, **21** Anaemic, **22** Full stop, **23** Tree

DOWN 1 Amethyst, **2** Rigel, **4** Resist, **5** Astronomical, **6** Secrete, **7** Cite, **8** Code breakers, **12** Menarche, **14** Epochal, **16** Mikado, **18** Emmer, **19** Wolf

#203 Multiple magic
Solution

32	1	128
64	16	4
2	256	8

Any magic square will produce a "multiplication" magic square if you raise a constant (k) to the power of each of the original magic square numbers. The smallest k that gives different answers is k = 2. Now, take the original magic square and work out 2^x for each value. The top row becomes 2^6, 2^1, 2^8 (64, 2, 256), which makes 2^{15} when multiplied together. These numbers can all be halved (32, 1, 128) to get the smallest solution, $2^{12} = 4096$.

Down with turtles

The fabled dominance of the hare by the tortoise has an underground counterpart of sorts in a look at turtles and elephants in times gone by. The elephants came out on top in a 2014 study called "Between the feet of elephants: Turtles as a common element of the associated fauna of proboscideans". But turtles hog all the attention in a new report called "100 million years of turtle paleoniche dynamics enable the prediction of latitudinal range shifts in a warming world".

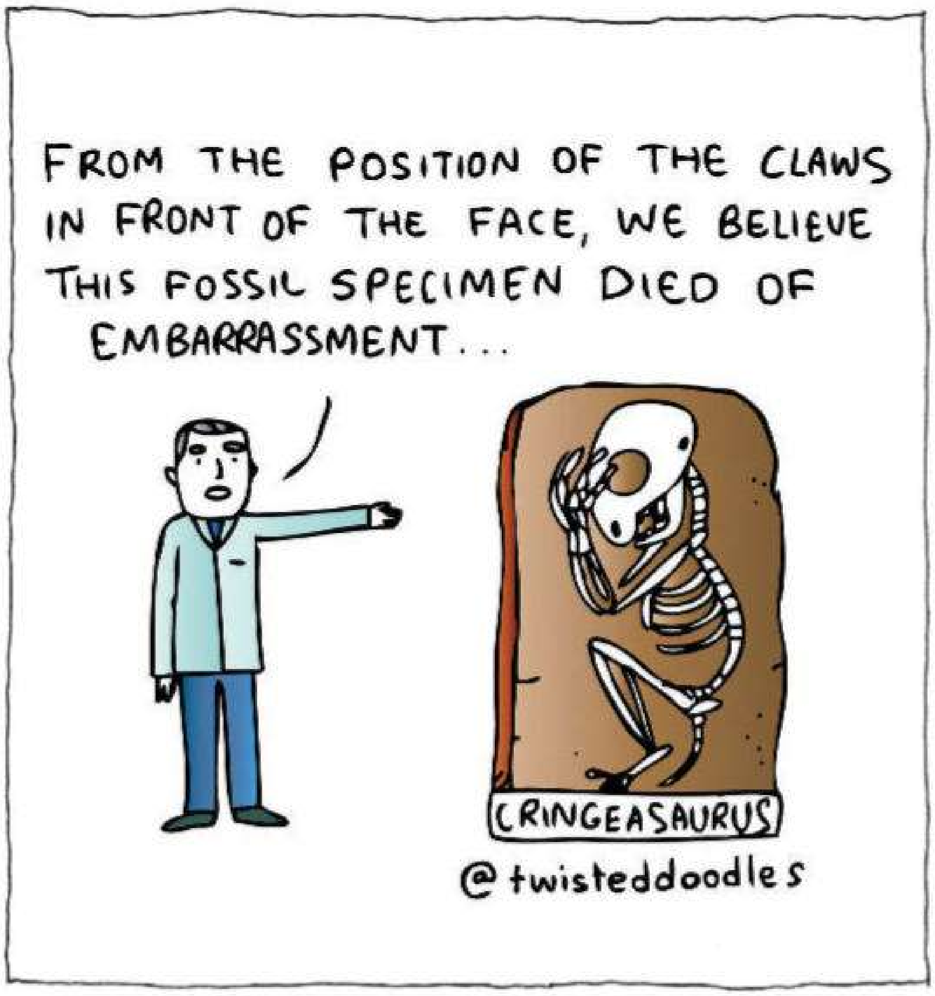
The two works serve as reminders that some old conjectures and beliefs really do stand atop shards of physical evidence. Myths, philosophies and Terry Pratchett's Discworld novels say that Earth rests on the back of a turtle, or maybe a stack of turtles, or perhaps some elephants on a stack of one or more turtles.

Turtle touters Alfio Alessandro Chiarenza, Amy Waterson and colleagues published their "100 million years" report in the journal *Current Biology* in 2022. It supports the supposition that it is turtles lots of the way (if not all the way) down.

The "feet of elephants" study, by Evangelos Vlachos, gives evidence that it isn't just turtles. Turtles and elephants are both turning up, down there below the surface of our world. Bits and pieces beneath Greece, Vlachos explains, show that "medium-sized to giant tortoises are found together with the proboscideans, in the humid environment of Epanomi [during the Pliocene] and the savannah-like environment of Axios valley [during the Late Miocene]".

The 2022 report warns that Greek turtles now living above the surface "will experience increases in both temperature and aridity over the coming century". It hazards no predictions for deep-subterranean turtles or elephants.

Twisteddoodles *for New Scientist*


FROM THE POSITION OF THE CLAWS IN FRONT OF THE FACE, WE BELIEVE THIS FOSSIL SPECIMEN DIED OF EMBARRASSMENT...
CRINGEASAURUS
@twisteddoodles

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Consideration of items sent in the post will be delayed

The man and his pea

The recent unearthing of the body of Gregor Mendel, so that modern scientists could analyse the DNA of the person who founded the science of genetics, makes possible a spectacular comparison, of man to pea. Mendel is famous for his experiments with pea plants, noticing characteristics that seemed to be passed from parents to their offspring.

Šárka Pospíšilová and her colleagues at Masaryk University in the Czech Republic laid out details of how they meddled with Mendel in several studies, one of which is called "Body remains of the founder of genetics Gregor Johann Mendel".

Thanks to them, it now becomes possible, and conceivably enlightening, to compare the DNA of Mendel with that of a pea plant. The plant's genome was published, for all to see, in 2019 in the journal *Nature Genetics*. Should you want to do your own digging, the Swiss Institute of Bioinformatics offers a tutorial called "What genes do I have in common with a plant?"

There remains the question: Why did Pospíšilová's team want to analyse Mendel's DNA? At a glance, it appears to be an example of Everest research. Everest research is done simply because the object of interest "is there". Comparing Mendel's DNA with that of a pea – should you choose to do it – would put a cherry on top of Mendel on top of a pea plant on top of Everest.

Although biologists treasure Mendel for his biological research, others treasure him for other reasons, some of which involve treasure. *Reason* magazine – slogan "free minds and free markets" – published an essay a few weeks ago. The title: "Gregor Mendel, the father of genetics and a tax resister, turns 200".

Hard to swallow

"There have been few reports of ingestion of bottlecaps worldwide." With that subtle statement, Mattis Bertlich, Friedrich Ihler, Jan Sommerlath Sohns, Martin Canis and Bernhard Weiss introduce a real-life detective story, told by the investigators themselves in the pages of the medical journal *Dysphagia*. Thanks to reader Friedrich von Bülow for alerting Feedback to this yarn.

The story began, from the narrators' point of view, when they "noted a peculiar cumulation of esophageal impaction of bottlecaps, particularly in [the context of] fraternity drinking rituals". The six investigators are medical professionals affiliated with institutions in Göttingen, Germany, a town noted for its university community. To begin the search for clues, they probed the wilds of a local database that harbours radiology records.

***Kronkorken* – the German term for bottlecap – was the key that unlocked the stash of evidence that confirmed their suspicions. Looking for this in the records turned up 14 cases of bottlecap ingestion within a 10-year period, with the ingestors all young men, all in Göttingen and all involved with fraternities. This contrasts with only six bottlecap ingestion cases, over a 30-year span, that the detectives managed to find when searching international medical databases.**

Twelve of the 14 Göttingen cases admitted knowing that a bottlecap had entered their body. The investigators remark on a curious pattern: "Interestingly, in all imaging findings, the bottlecap has nearly the same alignment in space, flat parallel to the spine." They don't speculate as to the whys or the therefores of that fact.

Capping their literary effort at its nether end, the authors offer a tidy warning: "This highlights the considerable dangers of excessive drinking rituals, as they are – to this very day – practised in fraternities, drinking societies and likewise." ▮

Marc Abrahams

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